ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Public Health Assessment for

LAWRENCE LIVERMORE NATIONAL LABORATORY,
MAIN SITE (U.S. DOE)
LIVERMORE, ALAMEDA COUNTY, CALIFORNIA
EPA FACILITY ID: CA2890012584
JUNE 29, 2004

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate.

In addition, this document has previously been provided to EPA and the affected states in an initial release, as required by CERCLA section 104 (i)(6)(H) for their information and review. The revised document was released for a 30-day public comment period. Subsequent to the public comment period, ATSDR addressed all public comments and revised or appended the document as appropriate. The public health assessment has now been reissued. This concludes the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

Agency for Toxic Substances & Disease Registry. . . . . Julie L. Gerberding, M.D., M.P.H., Administrator
Henry Falk, M.D., M.P.H., Assistant Administrator

Division of Health Assessment and Consultation. . . . . William Cibulas, Jr., Ph.D., Acting Division Director
Sharon Williams-Fleetwood, Ph.D., Deputy Director

Community Involvement Branch . . . . .Germano E. Pereira, M.P.A., Chief

Exposure Investigations and Consultation Branch. . . . . .Susan Moore, Acting Chief

Federal Facilities Assessment Branch. . . . . .Sandra G. Isaacs, Chief

Program Evaluation, Records, and Information . . . . Max M. Howie, Jr., M.S., Chief

Superfund Site Assessment Branch. . . . . Richard E. Gillig, M.C.P., Chief

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(703) 605-6000

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or
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PUBLIC HEALTH ASSESSMENT

LAWRENCE LIVERMORE NATIONAL LABORATORY, MAIN SITE (U.S. DOE)

LIVERMORE, ALAMEDA COUNTY, CALIFORNIA

EPA FACILITY ID: CA2890012584

Prepared by:

Energy Section
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

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FOREWORD

The Agency for Toxic Substances and Disease Registry, ATSDR, was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the *Superfund* law. This law set up a fund to identify and clean up our country's hazardous waste sites. The Environmental Protection Agency, EPA, and the individual states regulate the investigation and clean up of the sites.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each of the sites on the EPA National Priorities List. The aim of these evaluations is to find out if people are being exposed to hazardous substances and, if so, whether that exposure is harmful and should be stopped or reduced.
(The legal definition of a health assessment is included on the inside front cover.) If appropriate, ATSDR also conducts public health assessments when petitioned by concerned individuals. Public health assessments are carried out by environmental and health scientists from ATSDR and from the states with which ATSDR has cooperative agreements. The public health assessment program allows the scientists flexibility in the format or structure of their response to the public health issues at hazardous waste sites. For example, a public health assessment could be one document or it could be a compilation of several health consultations the structure may vary from site to site. Nevertheless, the public health assessment process is not considered complete until the public health issues at the site are addressed.

Exposure: As the first step in the evaluation, ATSDR scientists review environmental data to see how much contamination is at a site, where it is, and how people might come into contact with it. Generally, ATSDR does not collect its own environmental sampling data but reviews information provided by EPA, other government agencies, businesses, and the public. When there is not enough environmental information available, the report will indicate what further sampling data is needed.

Health Effects: If the review of the environmental data shows that people have or could come into contact with hazardous substances, ATSDR scientists evaluate whether or not these contacts may result in harmful effects. ATSDR recognizes that children, because of their play activities and their growing bodies, may be more vulnerable to these effects. As a policy, unless data are available to suggest otherwise, ATSDR considers children to be more sensitive and vulnerable to hazardous substances. Thus, the health impact to the children is considered first when evaluating the health threat to a community. The health impacts to other high risk groups within the community (such as the elderly, chronically ill, and people engaging in high risk practices) also receive special attention during the evaluation.

ATSDR uses existing scientific information, which can include the results of medical, toxicologic and epidemiologic studies and the data collected in disease registries, to determine the health effects that may result from exposures. The science of environmental health is still developing, and sometimes scientific information on the health effects of certain substances is not available. When this is so, the report will suggest what further public health actions are needed.

Conclusions: The report presents conclusions about the public health threat, if any, posed by a site. When health threats have been determined for high risk groups (such as children, elderly, chronically ill, and people engaging in high risk practices), they will be summarized in the conclusion section of the report. Ways to stop or reduce exposure will then be recommended in the public health action plan.

ATSDR is primarily an advisory agency, so usually these reports identify what actions are appropriate to be undertaken by EPA, other responsible parties, or the research or education divisions of ATSDR. However, if there is an urgent health threat, ATSDR can issue a public health advisory warning people of the danger. ATSDR can also authorize health education or pilot studies of health effects, full-scale epidemiology studies, disease registries, surveillance studies or research on specific hazardous substances.

Interactive Process: The health assessment is an interactive process. ATSDR solicits and evaluates information from numerous city, state and federal agencies, the companies responsible for cleaning up the site, and the community. It then shares its conclusions with them. Agencies are asked to respond to an early version of the report to make sure that the data they have provided is accurate and current. When informed of ATSDR's conclusions and recommendations, sometimes the agencies will begin to act on them before the final release of the report.

Community: ATSDR also needs to learn what people in the area know about the site and what concerns they may have about its impact on their health. Consequently, throughout the evaluation process, ATSDR actively gathers information and comments from the people who live or work near a site, including residents of the area, civic leaders, health professionals and community groups. To ensure that the report responds to the community's health concerns, an early version is also distributed to the public for their comments. All the comments received from the public are responded to in the final version of the report.

Comments: If, after reading this report, you have questions or comments, we encourage you to send them to us.

Letters should be addressed as follows:

Attention: Chief, Program Evaluation, Records, and Information Services Branch, Agency for Toxic Substances and Disease Registry, 1600 Clifton Road (E60), Atlanta, GA 30333.

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List of Abbreviations

1,1-DCE 1,1-dichloroethylene
Am ....americium
ATSDR ....Agency for Toxic Substances and Disease Registry
Bq........ ....becquerel
ºC......... ....degrees centigrade (or celsius)
CDHS.. ....California Department of Health Services
CERCLA..........Comprehensive Environmental Response, Compensation, and Liability Act of 1980
Ci......... ....curie
Cr ....chromium
CREG.. ....cancer risk evaluation guide
Cs ....cesium
Cu........ ....curium
DCA ....dichloroethane
DNAPL ....dense non-aqueous phase liquid
DOE ....Department of Energy
DTSC .. ..California Department of Toxic Substances Control
EMEGcc...........environmental media evaluation guide chronic (duration) child
EMEGic ....environmental media evaluation guide intermediate (duration) child
EPA ....Environmental Protection Agency
ºF ....degrees fahrenheit
FS ....feasibility study
HG....... ....health guideline
HT ....hydrogen--tritium gas
HTO ....tritiated water (hydrogen tritium oxygen)
ICRP.... ....International Commission on Radiological Protection
K.......... ....potassium
kg ....kilogram
L ....Liter
LLNL .. ..Lawrence Livermore National Laboratory
m ....meter
m^3 ....cubic meter
MCL.... ....maximum contaminant level
MCLG. ....maximum contaminant level goal
mg ....milligram
mg/kg .. ..milligram per kilogram
µg ....microgram
µg/L..... ....microgram per liter
$\mu g/m^3$ ... .microgram per cubic meter
MOE.... ....margin of exposure
mrem ... .millirem
MRL.... ....minimal risk level
NPL..... ....national priorities list
OBT ....organically bound trtium
OSHA.. ....Occupational Safety and Health Administration
PCE ....tetrachloroethyene

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PHA ....public health assessment
p ....(pico) 1 x 10^{-12}
PCBs ... .poly-chlorinated biphyenls
ppb ....parts per billion
ppm ....parts per million
Pu ....plutonium
Ra ....radium
RfC...... ....reference concentration
RfD...... ....reference dose
RI ....remedial investigation
RMEG. ....reference dose evaluation guide
RMEGc ....reference dose evaluation guide, chronic
RMEGcc ....reference dose evaluation guide, chronic, child
ROD ....record of decision
RWQCB...........Regional Water Quality Control Board
SARA.. ....Superfund Amendments and Reauthorization Act
SNL-L . ...Sandia National Laboratory- Livermore
SWRI .. ..site wide remedial investigation
TCE..... ....trichloroethylene
Th........ ....thorium
U.......... ....uranium
VOCs .. ..volatile organic compounds

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Summary

The Lawrence Livermore National Laboratory (Livermore Site; hereafter referred to as LLNL) is a multi-program research facility owned by the U.S. Department of Energy (DOE) and operated by the University of California. The LLNL is a science, technology, and engineering facility with a special focus on nuclear weapons research and development. Other areas of research include arms control and treaty verification control technology, energy, the environment, biomedicine, the economy, and education (DOE, 1992). LLNL was placed on the Superfund National Priorities List (NPL) in 1987 on the basis of volatile organic compounds (VOCs; trichloroethylene, tetrachloroethylene, chloroform, 1,1-dichloroethylene, and others) in monitor wells and nearby drinking water wells (LLNL, 1990). This public health assessment is required of all facilities on the NPL.

This public health assessment addresses potential off site (community) exposures to radioactive and non-radioactive hazardous substances released from the main site of the Lawrence Livermore National Laboratory (LLNL). The purpose of this public health assessment is to evaluate the potential for community exposures to, and potential health effects from, LLNL-released substances that may be present in off site ground water, surface water, soil and sediment, air, and locally grown foodstuffs. Specifically, this public health assessment will provide focused evaluations of the following public health issues:

- An assessment of the potential historic exposure doses to groundwater contaminants (this issue was the basis for the selection of the LLNL main site to the National Priority List (NPL) of the Environmental Protection Agency (EPA).
- An assessment of the public health hazard from exposure to LLNL-released hazardous substances that may be present in off site soil and sediment.
- An assessment of the potential cumulative radiological doses to members of the Livermore community. Doses from specific pathways, such as the accidental tritium releases and Pu-contaminated sewage sludge, have been individually addressed. This PHA will address the potential for cumulative ionizing radiation exposures to the different radionuclides.

In addition to the focused assessments of the above public health issues, this public health assessment will also evaluate the potential for community exposure to LLNL hazardous substances that may be present in off site surface waters, air, and locally grown foodstuffs, and determine whether the existing LLNL environmental monitoring program is adequate to assess the public health concerns of the Livermore community.

Releases of hazardous substances by LLNL (or the Naval Air Station that previously occupied the site) have resulted in the contamination of ground water, soil, surface water, air and biota in the Livermore community adjacent to the LLNL facility. The public health implications of those releases are evaluated in this PHA by a multi-step process that first identifies the LLNL contaminant sources and hazardous substances. The distributions and concentrations of these

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contaminants are then evaluated to determine if they were, are, or may be, present in areas of potential community exposure at concentrations of public health concern. Health protective (conservative) doses are calculated for those contaminants present in areas of potential community exposure. Finally, the public health implications of the estimated doses are determined relative to health comparison values derived from contaminant-specific health and toxicological studies.

Evaluation of the distribution and concentrations of those substances in the respective environmental media indicates that several contaminants (chromium-6, PCE, and TCE) are present in areas of potential community exposure at concentrations exceeding various health-based comparison values. Other contaminants above comparison values (boron, chromium, manganese, and nitrate) may be present in areas of potential exposure due to naturally occurring background concentrations or non-LLNL specific agricultural contamination. LLNL has also released measurable quantities of plutonium (Pu 239 and associated radionuclides) and tritium into the environment. Although previous assessments have determined that both short term and long term exposures to those radionuclides are below levels expected to produce any adverse health effects, due to community concern, these radionuclides are also considered to be contaminants of concern.

Community exposures to ground water contaminated by LLNL-specific contaminants (chromium-6, PCE, and TCE) were restricted to a few residences with private wells that were directly adjacent to the west boundary of the facility (circa 1983). There is no current ground water exposure to site-related contamination as the affected wells have been destroyed and some of the properties, which were purchased by DOE, are now on site. Other affected properties (west of Vasco Road) were provided with municipal water. Ongoing ground water remediation is also reducing the potential for future exposure to LLNL-related ground water contaminants at other locations. Potential exposure to non-LLNL related ground water contaminants (boron, chromium, manganese, and nitrate) is ongoing. The concentrations of Pu 239, tritium, and other radionuclides in areas of potential off site exposure are below levels of public health concern in all pathways and environmental media.

Estimated health protective doses, including the potential for cumulative doses across pathways, for the above preliminary contaminants of concern are below health comparison values (health guidelines) for all contaminants except boron, nitrate, and PCE. Estimated doses for boron and PCE are lower than any doses that have associated with adverse health effects in human or animal studies. Similarly, estimated maximum annual cumulative doses to Pu 239 and tritium from past accidental LLNL releases are less than 1/3 of natural background radiation doses and are not expected to cause any adverse health effects. Due to the health protective assumptions underlying these dose calculations, it is unlikely that members of the Livermore community were actually exposed to the maximum annual historic estimated doses and potential current exposures (less than 1 mrem/year) cannot be differentiated from the variation of natural background radiation.

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Potential ingestion of nitrate from ground water wells throughout the Livermore Valley may result in doses capable of producing adverse health effects. Based on the distribution of nitrate concentrations in monitor wells and a few drinking water wells, estimates of the 95th percentile doses represent a potential public health hazard. However, average and most likely doses are below levels of public health concern. Based on the distribution of elevated nitrate concentrations, the nitrate contamination is probably a result of widespread agricultural contamination and not related to the LLNL facility.

Based on the above findings, past and ongoing operations and releases from the LLNL facility, including the Naval Air Station previously on this site, are ***No Apparent Public Health Hazard***. This conclusion means that although community exposures to site-related contaminants may have, or be occurring, the resulting doses are unlikely to result in any adverse health effects and are consequently, below levels of public health concern.

Based on this review of the LLNL environmental monitoring program and the resulting analytical data, the available environmental information is adequate to address the public health concerns of the Livermore community. In order to ensure that releases from LLNL do not create future exposures of public health concern, ATSDR recommends that the current LLNL environmental monitoring program, as required for regulatory compliance with permitted air and water discharges, should be continued. Also, additional investigation of Livermore Valley private drinking water wells should be undertaken to ensure that areas of nitrate contamination (not related to LLNL releases or sources) are identified and that people are not drinking nitrate-contaminated water.

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Introduction

Scope and Organization of This Public Health Assessment

This public health assessment addresses potential off site (community) exposures to radioactive and non-radioactive hazardous substances released from the main site of the Lawrence Livermore National Laboratory (LLNL). The purpose of this public health assessment is to evaluate the potential for community exposures to, and potential health effects from, LLNL-released substances that may be present in off site ground water, surface water, soil and sediment, air, and locally grown foodstuffs.

Although a glossary of all technical terms used in this public health assessment is included as Appendix 1, it is necessary to preface this public health assessment with ATSDR's definition of several terms. *Hazardous substances* are chemicals or radioactive materials that have been released into the environment which could, under certain conditions, be harmful to people who come into contact with them. *Contaminants* (or environmental contaminants) are hazardous substances present in a person, animal, or the environment in amounts higher than some health screening value or the values found in uncontaminated areas. Using these definitions, this public health assessment will evaluate the distributions and concentrations of hazardous substances released by the LLNL to 1) determine whether those substances are present in the Livermore community as environmental contaminants and 2) determine whether those environmental contaminants represent public health hazards.

In order to understand and incorporate community public health issues related to the LLNL facility into this public health assessment, the Agency for Toxic Substances and Disease Registry (ATSDR) and the California Department of Health Services (CDHS) established the LLNL Site Team. This informal community forum is comprised of community members, state, local, and federal agency representatives, and representatives of several anti-nuclear activist groups. Collectively, this Site Team has identified a number of public health issues related to potential community exposures to LLNL related hazardous substances.

As summarized in the following section on "Public Health Activities at LLNL," many of the community public health issues identified by the LLNL Site Team have been addressed through a series of issue-specific reports developed by ATSDR and CDHS. The resulting health consultations and public health assessments specifically addressed the highest priority community health issues as determined by the Site Team. While a summary of those issues and conclusions of the health consultations is presented in a subsequent section, this public health assessment will focus on evaluating the community health issues that have not been previously evaluated.

Specifically, this public health assessment will evaluate the following public health issues:

- An assessment of the potential historic exposure doses to groundwater contaminants (this issue was the basis for the selection of the LLNL main site to the National Priority List (NPL) of the Environmental Protection Agency (EPA).

- An assessment of the public health hazard from exposure to LLNL-released hazardous substances that may be present in off site soil and sediment.
- An assessment of the potential cumulative radiological doses to members of the Livermore community. Doses from specific pathways, such as the accidental tritium releases and Pu-contaminated sewage sludge, have been individually addressed in previous PHAs. This PHA will address the potential for cumulative ionizing radiation exposures to the different radionuclides.

In addition to the focused assessments of the above public health issues, this public health assessment will also evaluate the potential for community exposure to LLNL hazardous substances that may be present in off site surface waters, air, and locally grown foodstuffs.

This assessment does not address on site exposures of LLNL workers to hazardous substances. LLNL workers may be exposed to hazardous substances at higher levels than the general public. Workers are trained in the use and safe handling of hazardous substances and their potential exposures are monitored by the LLNL Hazards Control Department.*

This document is comprised of three sections with supporting information included in appendices. This first section, the **Introduction**, presents information describing the LLNL facility and the surrounding community that is relevant to the subsequent public health evaluations. This section includes a brief description of land uses and population characteristics of the Livermore community that are relevant to the evaluation of environmental contaminants. This section also presents a summary of the Livermore community health concerns that may be related to the LLNL facility and a review of public health activities that have been conducted in response to those concerns.

The second section on **Environmental Contamination and Exposure Assessment** describes how ATSDR has evaluated the hazardous substances, the measured or estimated concentrations of each LLNL-related contaminant and describes the pathways of exposure and potential doses to community members. This section includes separate sub-sections for each potentially contaminated environmental media, such as air, soil, and ground water and evaluates each media for past, present and future exposures.

The last section, **Public Health Implications**, presents the potential health effects to community members for each contaminant for which off site exposure is known or presumed to have occurred (or may occur in the future). This section also evaluates available health outcome data and the community health concerns as they relate to the known health effects of the LLNL-related

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* The U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health (NIOSH) is responsible for researching potential workplace health hazards and developing recommendations related to occupational hazardous substance exposures.

substances present in off site areas.

Site Description and History

The Lawrence Livermore National Laboratory (Livermore Site; hereafter referred to as LLNL) is a multi-program research facility owned by the U.S. Department of Energy (DOE) and operated by the University of California. The LLNL is a science, technology, and engineering facility with a special focus on nuclear weapons research and development. Other areas of research include arms control and treaty verification control technology, energy, the environment, biomedicine, the economy, and education (DOE 1992).

The LLNL site is in southern Alameda County, California, and approximately 40 miles east of San Francisco (Figure 1). The LLNL is about three miles east of the central business district of the City of Livermore but directly abutted by residential properties to the west, commercial and industrial properties to the north, agricultural and residential land to the east, and the Sandia National Laboratory to the south. LLNL also operates the LLNL 300 site near Tracy, California (about 12 miles east of the main site). Operations and potential contaminant releases of the 300 site will be addressed in a separate public health assessment.

The LLNL main site, including a buffer zone acquired in 1989, covers an area of approximately 821 acres in the southeastern portion of the Livermore Valley. In 1942, the U.S. Department of the Navy acquired 681 acres of agricultural and ranch land to establish the Livermore Naval Air Station. Although the original use of the Naval Air Station was for flight training, by October 1944, aircraft assembly, repair, and overhaul was conducted at the Livermore NAS. From 1945 until the Livermore NAS was deactivated in 1946, extensive aircraft repair and assembly occurred at the site. In 1950, the site was occupied by the Atomic Energy Commission with formal transfer of the site in 1951. The AEC, it successor agencies and ancillary entities have occupied the site for defense-related research.

In 1952, the site was established as a separate part of the University of California Radiation Laboratory. In 1971, the Livermore site became the Lawrence Livermore Laboratory, and in 1979 was renamed by Congress as the Lawrence Livermore National Laboratory. Currently, LLNL is operated by the University of California under contract with the U.S. Department of Energy.

In 1992 DOE published the "Final Environmental Impact Statement and Environmental Impact Report for Continued Operation of the Lawrence Livermore National Laboratory and Sandia National Laboratories, Livermore" (DOE 1992). This document includes a detailed statement of LLNL operations and facilities. The information from that report outlining LLNL operations and facilities will not be reproduced here, but will be referenced as appropriate to define environmental releases and potential community exposures to chemical and radiological materials.
LLNL was placed on the Superfund National Priority List (NPL) in 1987 on the basis of volatile

organic compounds (VOCs; trichloroethylene, tetrachloroethylene, chloroform, 1,1-dichloroethylene, and others) in monitor wells and nearby drinking water wells (Thorpe et al. 1990).

Community Health Concerns and Public Health Activities related to the LLNL

ATSDR and CDHS have completed several public health activities related to the LLNL site in response to specific community health concerns. This section will present the communities concerns related to the LLNL main site facility and briefly review the completed public health documents related to those concerns. Additional information on the details of these public health evaluations will be discussed in following sections on environmental pathways and public health implications. The published health consultations and public health assessments, although not included verbatim, are considered part of this PHA by reference.

In 1997, ATSDR and CDHS created an informal working group of individuals with environmental, health, and community expertise to enhance the ATSDR public health assessment process. The stated purpose of this site team is to help identify and prioritize health topics addressed in the PHA or health consultations, to review and comment on draft documents, and to facilitate communication between governmental agencies and the Livermore community. The priority issues and related public health actions identified by the site team are listed in Table 1. Many of the issues identified by the site team have been addressed as published health consultations or PHAs (described below) and the remaining public health topics are discussed in this PHA. The site team continues to facilitate communication with the Livermore community and to review and comment on draft public health documents.

Specific public health documents related to the LLNL site are as described:

- *Preliminary Public Health Assessment* (ATSDR 1989): ATSDR completed a preliminary public health assessment of the LLNL site in 1989. This preliminary assessment concluded that the site was of potential public health concern but that more information was necessary to evaluate those concerns.

- *Health Consultation on Water Quality of the Municipal Water Suppliers ....* (ATSDR 1999a): CDHS completed a review of potential contamination of public water supply wells and concluded that there has been no impact on public water supplies. One of the recommendations of the consultation was to further evaluate contaminant distributions and potential exposures to contaminated groundwater from private drinking water wells. That recommendation is addressed in this PHA.

- *Health Consultation on Plutonium Contamination in Big Trees Park* (ATSDR 1999b): Following the release of two reports (EPA 1994a; LLNL 1995) indicating the presence of elevated levels of plutonium in a small park located about ½ mile west of LLNL, CDHS evaluated the potential community health effects from plutonium exposure at the park. The consultation also evaluated several processes by which the plutonium reached Big Trees Park. The consultation concluded that plutonium concentrations are below levels of public health concern and that placement of contaminated sludge was the most probable source of the plutonium. The consultation also recommended additional sampling and further review of possible source processes.

- *Health Consultation on Big Trees Park 1998 Sampling* (ATSDR 2000): Follow-up sampling of Big Trees Park was conducted through a multi-agency sampling program in order to further evaluate plutonium distribution and possible sources at Big Trees Park. This consultation analyzed the resulting data and concluded that maximum activities were no higher than previously detected and reiterated that those levels are not of public health concern. No additional recommendations were developed.

- *Health Consultation on Lawrence Livermore National Laboratory Community Health Concerns* (ATSDR 2003a): The purpose of this health consultation was to review and document community health concerns related to the LLNL facilities (Main Site and Site 300). Health concerns have been collected by several different processes including telephone and door-to-door surveys and through a series of community meetings. The consultation lists all concerns identified by those processes and the actions or responses to those concerns. The most frequently identified concerns, including the safety of the municipal water supply, plutonium in nearby parks, and potential tritium exposures have been addressed by health consultations and are summarized in Table 1.

- *Health Consultation on "Review of Health Studies Relevant to Lawrence Livermore National Laboratory and the Surrounding Community*" (ATSDR 2003b): CDHS has addressed concerns about the incidence of melanoma and other potential adverse health effects with a review of completed health studies. In general, there does not appear to be an increased incidence of diseases, including cancer, for the areas adjacent to LLNL in relation to other nearby, or control, areas. Historically elevated rates of melanoma are probably due to increased surveillance of the LLNL population and known exposure factors (such as behavioral exposure to sunlight). Current melanoma rates do not appear to be elevated relative to other control populations. Continued monitoring and study of the potential association of melanoma with radiological exposures is recommended.

- *Health Consultation on "Tritium Releases and Potential Off site Exposures*" (ATSDR 2002): ATSDR addressed concerns about potential tritium exposures and the processes of tritium monitoring and dose calculation at LLNL by convening an expert panel to review current knowledge of tritium dosimetry and site specific monitoring information. The expert panel report is included as an attachment of the health consultation which summarizes the report. The consultation concludes that current dose calculations underestimate total tritium exposures by neglecting potential dose contributions from ingestion of organically bound tritium (by a factor of about 1.2 to 1.3), but that the overall doses at LLNL are below levels of public health concern. The consultation further concludes that although organically bound tritium is not directly monitored at LLNL, existing data on the ratios of tritium in water and organic matter are sufficient to assess organically bound tritium dose contributions. The consultation recommends that LLNL continue its current program of tritium monitoring.

- *Public Health Assessment on "Exposure Assessment of 1965 and 1970 Accidental Tritium Releases from the Lawrence Livermore National Laboratory*" (ATSDR, 2003c; the summary of this PHA is included as Appendix 2):* The review and evaluation of tritium dosimetry and exposure issues by the expert panel (ATSDR 2002) focused on chronic environmental tritium doses. However, more than 80% of LLNL tritium releases occurred during two accidents. ATSDR used the dose calculation methodology recommended by the expert panel and air dispersion models to evaluate potential acute tritium doses. The assessment concluded that estimated tritium doses are below levels of health concern. Additionally, measured tritium body burdens during the 1970 release suggest that modeled doses overestimate the actual doses. As estimated tritium levels were below levels of public health concern, no recommendations were developed.

- *Public Health Assessment on "Plutonium 239 in Sewage Sludge Used as a Soil or Soil Amendment in the Livermore Community*" (ATSDR 2003d; the summary of this PHA is included as Appendix 3): This PHA found that Pu 239 and related nuclides were historically released to the Livermore Water Reclamation Plant from several accidental events. Processed, Pu-contaminated sludge from the treatment plant was historically distributed to the Livermore community. Potential maximum radiological doses from this sludge are below levels of public health concern. Although it is recommended that LLNL continue monitoring sewer effluent for future release events, no additional recommendations concerning the historic releases are warranted.

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*The PHA was originally released for public comment as a health consultation in 2001. Due to extensive revision based on public comments, the evaluation was re-released as a PHA with additional public and peer review comments.

Table 1. List and status of public health issues identified by the LLNL PHA Site Team. The priority issue list is included in the ATSDR (CDHS) health consultation (2003a).

LLNL Site Team Priority Issue	**Status and Public Health Actions**
1) More complete sampling effort in Big Trees Park that would include Sycamore and Sunflower Parks	1a) Two health consultations completed: ATSDR 1999; ATSDR 2000. Potential exposures are below levels of public health concern.
2) A closer examination of melanoma rates in Livermore	2a) 12 studies or study reviews completed concluding that the melanoma incidences among LLNL workers are not related to occupational exposures. 2b) CDHS completed a review of the above health studies related to melanoma and other health effects (ATSDR 2003b).
3) Health impacts of cumulative exposures	3a) An ATSDR PHA (2003c) addressed cumulative short and long term tritium exposures. 3b) Other cumulative exposures are addressed in this PHA
4) Past and present air emissions from LLNL	4a) An ATSDR health consultation and a PHA have addressed past and present tritium air releases, which are below levels of public health concern (ATSDR 2002, 2003c). 4b) Other LLNL air emission sources are evaluated in this PHA.
5) Adequacy of existing tritium monitoring procedures	5a) An expert panel review of LLNL tritium levels and testing methods was included in an ATSDR health consultation (2002). The panel report concluded that available monitoring data are adequate for public health assessment.
6) Confirmation of the safety of Livermore's drinking water	6a) An ATSDR (1999a) health consultation confirmed the safety of Livermore's drinking water supply. 6b) This PHA evaluates potential exposure doses from residential wells.
7) A closer examination of LLNL melanoma rates	See number 2 above. As LLNL worker melanoma cases are not related to occupational exposures, any community cases will not be related to LLNL contaminant exposures.

Table 1. List and status of public health issues identified by the LLNL PHA Site Team. The priority issue list is included in the ATSDR (CDHS) health consultation (2003a).	
LLNL Site Team Priority Issue	**Status and Public Health Actions**
8) Need for a review of health studies	CDHS has completed a review of health studies. See number 2 above.
9) Bio-monitoring for plutonium	9a) An ATSDR PHA (2003d) evaluated community exposures to Pu-contaminated sewage sludge and found potential exposures below levels of public health concern. 9b) This PHA evaluates potential plutonium exposures to the LLNL community via sediment and soil.

Land Use and Natural Resources of the Livermore Area

The LLNL site is extensively developed with large-scale experimental research and support facilities. Immediately north of the site, land is zoned for and used for industrial activities. West of the site, land is high density urban/suburban, although much of the development has occurred quite recently. South of LLNL is the Sandia National Laboratory-Livermore (SNL-L), which is functionally very similar to LLNL. Land east of LLNL is zoned for agriculture and currently used as pasture land.

The ground surface of the LLNL site is flat with a slope of 1 percent or less (from southeast to northwest). LLNL and the Livermore Valley are underlain by up to 4000 ft. of interbedded alluvial sediments that infill a structural depression. The interbeds are comprised of clays, silts, sands and gravels deposited as alluvial fans, terraces, and flood-plain deposits eroding off of the surrounding Diablo Range (Carpenter 1984). Surface runoff from the LLNL site is drained by two ephemeral streams (Arroyo Seco and Las Positas) that both flow to the northwest.

The climate of the Livermore area is typified by warm, dry summers and mild, wet winters. Most (90 %) of the average annual rainfall of 14 inches is the result of short storms during winter months (November--April; Thorpe, et al. 1990a). Direct infiltration of rainfall accounts for about 40 % of groundwater recharge. Indirect infiltration, via stream beds and ponds/retention areas accounts for about 42 % of groundwater recharge. Applied water from irrigation accounts for the remaining 18 % of recharge.

Winds are predominantly from the south and southwest (61 percent) with calms representing another 26 percent of total (wind speed less than 1 m/s; Thorpe, et al. 1990a). Summer winds, almost always from the south or southwest, have a higher frequency of high wind speeds as a result of sea breezes or differential heating blowing up the Livermore Valley. Winter wind directions are most frequently from the north as a result of winter storms, with a secondary maximum from the south (LLNL 1990a).

Intermittent surface water runoff from the LLNL site is comprised of storm-water runoff and treated effluent from the LLNL groundwater recovery system. Historically, cooling water and other process waters were discharged to the storm sewers. Treated effluent discharged to the streams is regulated by the Regional Water Quality Control Board and must meet specified effluent limitations before it is discharge (LLNL 1990a). Some surface water is routed to an excavated, lined, drainage retention basin located in the central portion of the LLNL site.

Beneficial uses of surface waters are limited due to the intermittent nature of the streams (flow occurs only during the winter rainy season). Use of the streams for wildlife habitat is also limited due to channelization and fences that restrict wildlife access (LLNL 1990a). The retention basin and the streams represent significant sources of groundwater recharge which is the primary beneficial use of surface waters (LLNL 1990a).

Population Characteristics of the Livermore Area

The population characteristics of the area surrounding the LLNL facility are shown in Figure 1. An area-proportion method was used to estimate the population within one mile of the borders of the site. From the 2000 census data, approximately 8,000 people live within one mile of the facility in 2751 housing units. Relative to past potential exposures, in 1970, 3,165 persons lived within this same area. Total population in 1980 was 3,810, an increase of just over 20 %. Over 97 % of the population was white in 1970, and 90 % in 1980; however, those numbers may not be comparable due to differences in the racial categories used by the Census Bureau in the two censuses.

The number of persons age 65 or older nearly doubled, from 108 in 1970 to 196 in 1980. Children age 6 or younger actually declined, from 445 in 1970 to 413 in 1980. In 1970 there were 716 women between ages 15 and 44, which approximates the childbearing years, and in 1980 there were 958. Children, adults over age 65, and fetuses in pregnant women may be especially susceptible to adverse health effects from exposures to hazardous substances. The following sections explicitly estimate doses to children and adults and the public health implications of those doses. The population characteristics of the specific areas affected by the 1965 and 1970 tritium releases are presented in the PHA on that topic (ATSDR 2003c).

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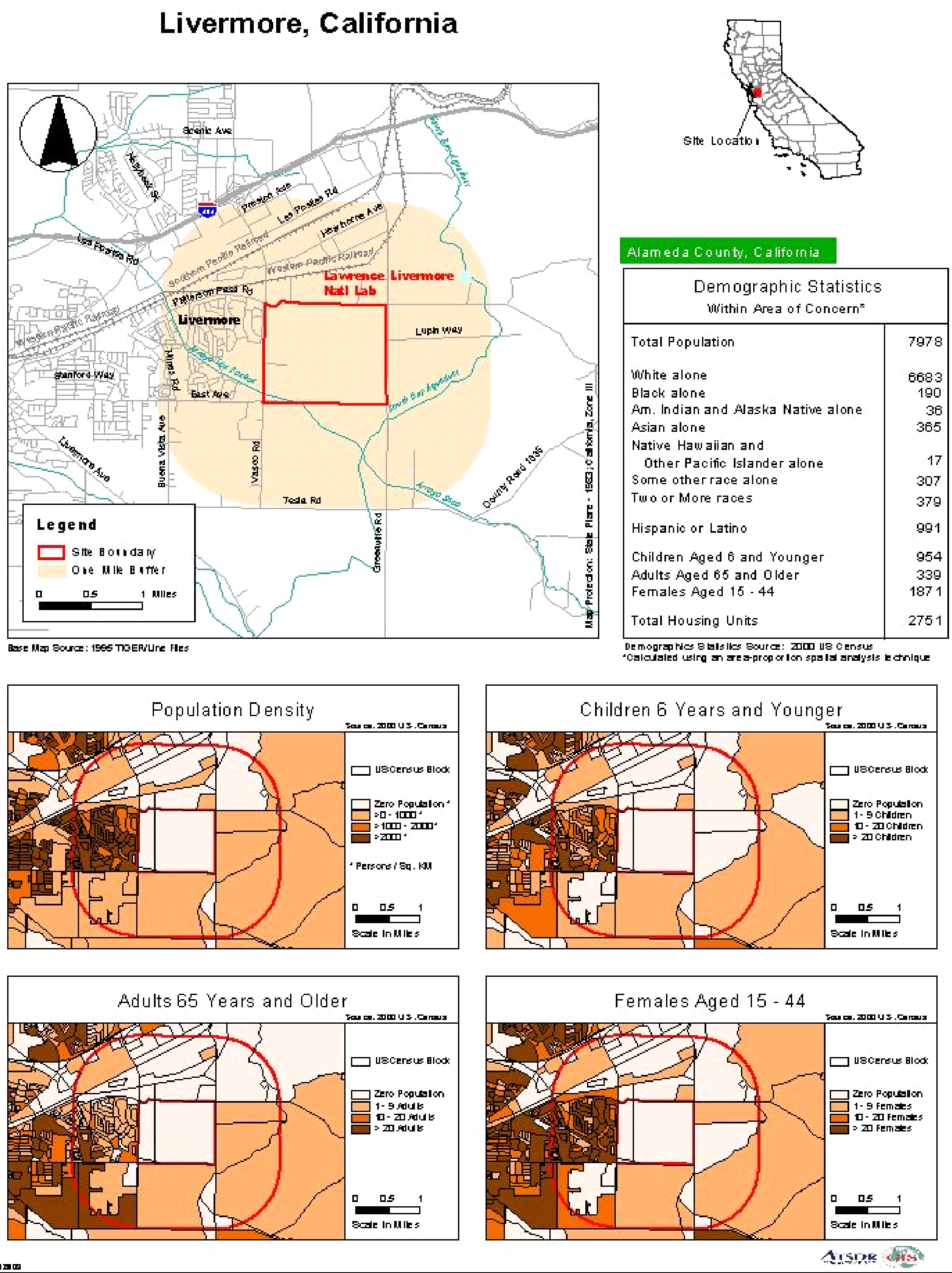
Figure 1. Population characteristics of the area surrounding the Lawrence Livermore National Laboratory



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Environmental Contamination and Exposure Assessment

Introduction
This section discusses the sources and concentrations of various chemicals and radioactive materials (contaminants) evaluated for this site, how people may come into contact with them, the potentially exposed populations, and if exposed, the potential exposure doses.

The concentrations and distributions of chemicals and radioactive materials are evaluated in ground and surface water, air, soil and sediment, and food products to determine if contaminants are at levels of health concern in areas of human exposure. Not all contaminants from the site are at levels that pose a health hazard.

A release of a chemical or radioactive material from a site does not always mean that this substance will be a contaminant of health concern to an off site population. ATSDR scientists first determine if a chemical or radioactive substance in water, air, soil, or biota (plants and animals) should be considered a "*contaminant of (public health) concern.*" The criteria used include (1) whether environmental levels exceed media-specific comparison values, (2) noted community health concerns, and (3) the quality and extent of sampling data with which to evaluate potential exposure and human health hazard. For inorganic compounds (metals) and radionuclides, background values may also be considered, since some of these substances occur naturally. For all potential contaminants, the highest environmental concentration detected off site is compared with media-specific comparison values to determine if further evaluation is warranted. Comparison values (or health comparison values; CVs) may be either environmental concentrations, in media-specific concentration units (such as ppb or pCi/L, etc.) or health guidelines in units of dose (such as milligrams per kilogram body weight per day; mg/kg/day or mrem/year). The basis and derivation of the comparison values are described in Appendix 4.

Identification of contaminants of concern is a multi-step process. First, the maximum concentrations of all materials for both on site and off site locations are compared with media specific health comparison values (CVs). If the contaminant concentrations exceed one or more CVs, then the sample locations and contaminant concentrations are evaluated to determine the contaminant concentrations in areas of potential community exposure. If exposure to an elevated concentration is likely, the contaminant is considered a preliminary contaminant of concern and a dose is calculated based on the measured or estimated contaminant concentrations and appropriate exposure factors. The resulting doses are compared with health guidelines (HGs) in the following section on Public Health Implications to determine whether the estimated doses are likely to cause adverse health effects.

A release of a chemical or radioactive material into the environment does not always result in *human exposure*. For an exposure to occur, a completed *exposure pathway* must exist. A *completed exposure pathway* exists when the following five elements are present: (1) a source of contamination, (2) an environmental medium through which the contaminant is transported, (3) a point of human exposure, (4) a route of human exposure, and (5) an exposed population.

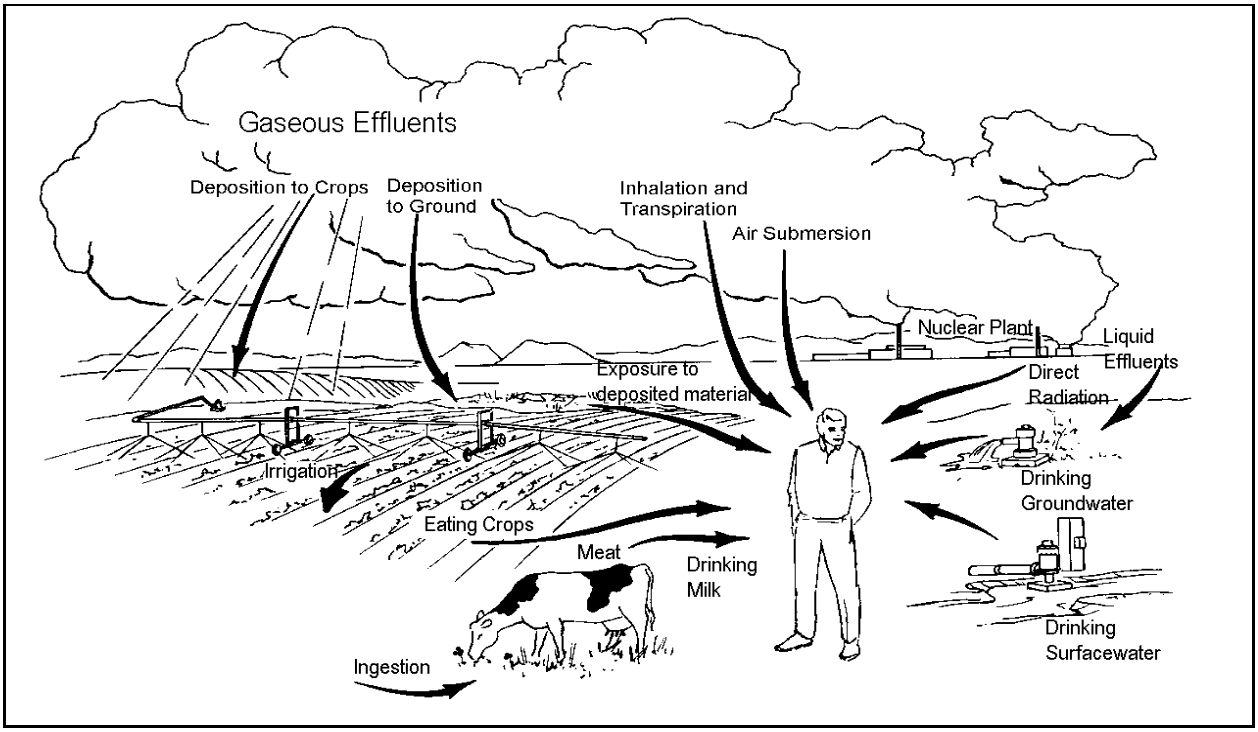

Figure 2. Illustration of the pathways of exposure from site releases of hazardous substances to members of the off site community. The concentrations and distributions of hazardous substances in each of the pathways are evaluated in this section.

A potential exposure pathway exists when one or more of the elements are missing, but available information indicates that human exposure is likely to occur. *No exposure pathway* exists when one or more of the elements are missing, and available information indicates that human exposure is unlikely to occur (ATSDR 1992). Figure 2 illustrates the necessary components of an exposure pathway.

In addition, for each pathway, ATSDR scientists identify whether releases of contaminants and exposures are likely to have occurred in the past, present, or potentially in the future. If the pathway is complete or potentially complete, pathway specific exposure doses are estimated based on the type of exposure and the measured or calculated contaminant concentrations. The potential health effects of the resulting exposure doses are evaluated in the Public Health Implications section of the public health assessment.

For purposes of this report, *on site contamination and releases* describes contamination and releases of material within the fenced security area of the site or in areas for which public access is restricted. Off site *contamination* describes environmental media (soil, sediment, surface water, ground water, air, or food-chain entities) that are contaminated as a result of hazardous or radioactive contaminants leaving the site and are no longer being controlled by DOE or LLNL. In this report, on site sources of contamination are being considered only as sources of off site contamination or for their impact on the community. The impact of potential contaminant exposures to LLNL workers is outside the legislative mandates of ATSDR and is evaluated by other organizations.

The remainder of this section on environmental contamination will present media-specific sub-sections on ground water, surface water, soil and sediment, air, and biota (foodstuffs). Each sub-section will include a review of potential LLNL contaminant sources, an evaluation of the preliminary contaminants of concern for that medium, and a determination of whether the pathways of exposure are complete, potentially complete, or incomplete. For complete or potentially completed pathways, exposure doses will be calculated for consideration in the following section on Public Health Implications.

Ground Water

Background

The Livermore Valley contains significant groundwater resources. The primary water-bearing aquifer is within the Livermore Formation, which is comprised of semi-indurated to unconsolidated lacustrine, fluvial, and alluvial deposits (Carpenter 1984). These heterogeneous deposits consist of clays, silts, sands and gravels that are vertically inter-bedded with limited horizontal continuity (Carpenter 1984). Groundwater flow in these deposits occurs preferentially in the sands and gravels. Deposition of sands and gravels occurs along the margins of the alluvial basins and along the paleo-stream channels (Selley 1988). Paleo-stream channels underlie and mimic the Arroyo Seco and Las Positas streams which create zones of preferential groundwater flow (LLNL 1990a).

In the vicinity of LLNL, there are two water-bearing units within the Livermore Formation separated by a horizontally extensive layer of low permeability lacustrine silts and clays. The upper water-bearing unit (QT1) varies from less than 100 ft to more than 500 ft in thickness. Groundwater in QT1 is largely unconfined (a water table aquifer) with some deeper zones semi-confined by laterally discontinuous confining beds. Depth to the saturated upper surface of QT1 varies from over 130 ft in the southeast corner of LLNL to less than 30 ft in the Rhonewood Subdivision west of the LLNL facility (LLNL 1990a). Lacustrine (lake) deposits within the lower member of the Livermore Formation (Tpl) apparently restrict exchange between the upper and lower water bearing units. Since 1985 LLNL has destroyed and sealed wells in the vicinity of the contaminant plumes that had the potential to serve as conduits for cross-contamination of various water-bearing intervals (Dresen and Nichols 1986). Table A-3 (Appendix 5) contains an inventory and status of private wells adjacent to LLNL.

The regional groundwater flow direction is towards the west-central portion of the Livermore Valley. In the vicinity of the LLNL site, groundwater flow is generally west-northwest with horizontal hydraulic gradients of 0.001 to 0.005 (LLNL 1990a). Vertical hydraulic gradients are downward with significant local variation in magnitude. In the eastern portion of the LLNL facility, vertical gradients are greater than 0.20 ft/ft, while on the west side of LLNL the gradients decrease to 0.03 ft/ft or less (LLNL 1990a). Groundwater levels in the LLNL vicinity have been rising since the 1960s as a result of decreased groundwater pumping (LLNL 1990a)

Groundwater in the Livermore Valley is used for public and private drinking water supplies, agricultural irrigation and livestock, and industrial supply. The groundwater quality in the LLNL vicinity generally meets the requirements for those uses. Both public and private supply wells are located down-gradient of the LLNL facility. A Health Consultation prepared by the California Department of Health Services in cooperation with ATSDR evaluated the water quality of the down gradient public water supply wells and concluded that LLNL contamination has not affected those wells. The remainder of this document will evaluate the potential for contamination of the private drinking water supply wells.

Ground Water Contaminant Sources

Investigation of contaminant sources at LLNL have been ongoing for several years and documented in numerous reports including the five volume CERCLA Remedial Investigations report (LLNL, 1990a); the CERCLA Feasibility Study (Isherwood et al. 1990); LLNL Annual Environmental Reports (LLNL various years); and LLNL Groundwater Monitoring Program Annual Reports (LLNL various years); and numerous reports on specific source investigations and remedial actions. Groundwater VOC contamination exists under approximately 90% of the LLNL site, however, much of this contamination is attributed to past operations and waste disposal activities from naval airfield operations prior to establishment of LLNL (LLNL 1990a).

Areas of significant residual contamination and more recent or ongoing LLNL sources are presented in Table 2. This table also indicates whether these contaminated areas or sources have potentially contributed to off site exposure and if ongoing remediation has contained or removed the potential for current or future exposure. Because these historic sources no longer exist and the resulting contamination consists of multiple and sometimes overlapping plumes, detailed description of the individual sources will not contribute to increased understanding of VOC exposure and migration. Information on source areas of specific contaminants will be presented in following sections as necessary for understanding contaminant transport and potential exposure.

In addition to the VOC sources from Naval airfield operations, LLNL operations are also responsible for releases of fuels, VOCs, other chemical contaminants (i.e., PCBs and metals), and radiological materials (primarily tritium). Off site industrial and agricultural operations have also resulted in groundwater contamination (VOCs, chromium, and nitrate). These sources, along with their potential for past exposure and current status are also listed in Table 2. Current operating procedures for the use, disposal, and accidental spill response for hazardous materials are significantly improved relative to historic practices such that there are unlikely to be any significant future ground water contaminant sources.

Current and historical groundwater monitoring has not detected any VOC concentrations approaching solubility limits, which indicates that there are no dense non-aqueous phase liquids (DNAPLs) in the subsurface. DNAPLs, if present, would constitute a long-term subsurface contaminant source. Remediation of contaminant sources and dissolved phase groundwater contaminants is ongoing.

The ground water data evaluated in this PHA is adequate for determination of the public health assessment of LLNL specific contaminant concentrations and distributions. However, the data set on which this assessment is based is not adequate for complete evaluation of non-LLNL or background ground water contamination throughout the Livermore Valley.

Table 2. Potential source areas and status for groundwater contaminants. Current hazardous material handling procedures make current or future ground water contamination unlikely.

Source Area	**Source Description and Contaminants**	**Comments and Status**
Arroyo Seco Storm Discharge Area	Storm sewer discharges into Arroyo Seco; little quantitative information available; Possible source of PCE and TCE	Historic source of highest off site PCE concentrations; PCE/TCE use discontinued; Storm drains rerouted to retention pond.
Bldg. 212 Area	LLNL machine, plating, and electronic shops (VOCs and metals) and possible radioactive material spills	Non-radioactive hazardous wastes are used and stored in this area.
Bldg. 321 Area	Plating/machine shops, probable VOC source incl. PCE, 1,1-DCE, paints, and other materials.	Hazardous wastes are used and stored in this area
Bldg. 141 Area	Staging area for Nevada Test Site materials, electrical engineering facility ~1960; oils, solvents, metals,	Electrical engineering facility

Table 2. Potential source areas and status for groundwater contaminants. Current hazardous material handling procedures make current or future ground water contamination unlikely.		
Source Area	**Source Description and Contaminants**	**Comments and Status**
West Traffic Circle/Bldg. 361 Area	Former Naval Air Station landing mat; possible releases via open storm sewer drainage; former fire training areas	Laser Program, Biomedical and Environmental Programs, Technical Services-- unlikely contaminant sources
East Traffic Circle Area	Former runway aprons with airplane degreasing (TCE); LLNL landfill with metals, PCBs, hydrocarbons, and radioactive materials	Contaminated materials and soils removed ~1985
East Taxi Strip Area	Former taxi strip with airplane cleaning and repairing (TCE); LLNL evaporation ponds and disposal pits (VOCs, tritium, radioactive materials).	Taxi strip, evaporation ponds, and disposal pit soils have been removed (1982--83).
East Landing Mat Storage Area	Salvage and storage of chemicals and oils (solvents, PCBs, hydrocarbons, and other materials).	Ground water and soil remediation are ongoing.
Old Salvage Yard Area	Storage area for chemicals, solvents, oils, mercury, and scrap metal.	The salvage yard was relocated in 1979. Area is currently a parking lot, characterization ongoing.
Bldg. 612 Area	Solid waste holding and shipping facility for chemicals, solvents, oils, mercury, and scrap metal.	Still in use pending transfer to LLNL's recently constructed Decontamination and Waste Treatment Facility.
Bldg. 514 Area	Former aircraft engine repair facility; LLNL waste disposal and decontamination facility (radioactive waste materials, VOCs, hydrocarbons	Still used as waste disposal and decontamination facility pending transfer to LLNL's recently constructed Decontamination and Waste Treatment Facility.
Bldg. 518 Area	Gas cylinder, solvent, and oil drum storage facility (VOCs).	Still used as storage area. Ground water and soil remediation ongoing.
Bldg. 298/Fire Training Area (fire training area pre-dates LLNL facility)	Kerosene, gasoline, and jet fuel were ignited in pans for fire training activities.	Ground water and soil remediation is ongoing.
Gasoline Spill Area	Four 10,000 gal. underground gasoline tanks with documented leakage.	Tanks filled with sand in 1980. Groundwater remediation has removed large portion of fuel hydrocarbons and is ongoing.

Table 2. Potential source areas and status for groundwater contaminants. Current hazardous material handling procedures make current or future ground water contamination unlikely.		
Source Area	**Source Description and Contaminants**	**Comments and Status**
Salinas Reinforcing/Richmond Lox, Inc.	Industrial facility ~1000 ft. NW of NW LLNL boundary. Documented source of TCE, nitric and chromic acids.	Source of highest off site TCE concentrations.
Nitrate --Various Locations	Nitrate analyses indicate at least four off site source areas probably due to agricultural and industrial activities.	Agricultural activities adjacent to LLNL have been greatly reduced due to residential development of agricultural lands.
Water cooling towers	Hexavalent chromium used as corrosion inhibitor in cooling water	Use of chromium discontinued ~1970

Ground Water Preliminary Contaminants of Concern

This assessment of ground water contamination at the LLNL site includes evaluation of more than 566,000 analytical records from more than 550 monitor and private wells. The preliminary list of contaminants detected in ground water includes the maximum concentrations, number of detections, and the location of those detections (Table 3). This table also indicates whether each contaminant is a preliminary contaminant of concern based on contaminant concentrations in areas of potential exposure to the LLNL community. Identification as a preliminary contaminant of concern indicates that additional evaluation is required to determine the potential for exposure but does not necessarily indicate that exposure has occurred. Subsequent sections will document exposure potential and exposure doses if exposure has or is likely to occur.

Eight chemical contaminants have been identified as preliminary contaminants of concern (boron, chromium (total; referred to as chromium), hexavalent chromium (referred to as chromium-6), manganese, nitrate, benzene, tetrachloroethylene, and trichloroethylene). The distributions of tetrachloroethylene (PCE) and trichloroethylene (TCE) are shown in Appendix 5. Both of these contaminants are widely distributed across the LLNL facility and the predominant sources may be due to extensive use and disposal by the naval airfield.

The primary off site PCE plume occurs along Arroyo Seco in the southwest corner of the LLNL facility and probably originates from storm sewer runoff into the Arroyo (Table 2). The maximum off site PCE concentration was 490 ppb and several residences with drinking water wells were present in this area before 1988. TCE concentrations along Arroyo Seco are much lower (~50 ppb) and do not appear to have migrated as far as PCE. Potential PCE and TCE exposures and exposure doses are evaluated in the following sections. Much higher TCE concentrations (> 1000 ppb) are located in the northwest corner of the LLNL facility and the off site plume in this area is largely due to the Richmond Lox source (Iovenitti et al. 1991). However, there are no residential drinking water wells located in this industrial area (Appendix 5).

Based on United States Geological Survey data (USGS 2000), boron and manganese have background concentrations greater than their respective comparison values. On site concentrations of boron are similar to off site concentrations indicating that there is not a significant LLNL-related source of elevated boron concentrations. On site concentrations of manganese are much higher than off site locations which may indicate potential on site sources. However, the LLNL Remedial Investigation Report (LLNL 1990) indicates that the manganese concentrations may be due to background levels of manganese oxide. Although both boron and manganese may be naturally-occurring, potential exposures will be evaluated to determine if adverse health effects are possible.

Chromium and chromium-6 have on site and off site concentrations greater than their respective comparison values. LLNL cooling water used a chromium-6 anti-corrosion agent until about 1970 (LLNL 1990). This water was released from the cooling towers through the surface water drainage system with subsequent seepage into the ground water system. An industrial facility (Richmond Lox) also apparently used chromic acid in metal plating and cleaning operations. The distribution of chromium-6 concentrations is illustrated in Appendix 5. The highest off site values are located around the northwest corner of the LLNL facility and may be due to ground water recharge from cooling tower runoff and/or the Richmond Lox facility.

The distribution of nitrate at several up-gradient and cross-gradient off site wells suggests multiple off site sources. Nitrate is a common agricultural and domestic wastewater contaminant. Elevated ground water concentrations are common throughout the Livermore Valley as a result of past and present agricultural sources (Sorenson et al. 1985). Based on contaminant source characterizations and distributions, LLNL is an unlikely source for off site nitrate contamination. However, measured concentrations in drinking water wells do require evaluation of potential exposures.

Benzene concentrations exceeded the health comparison values with maximum off site monitor well concentrations greater than 500 ppb (Table 3). The distribution of benzene is restricted to the gasoline spill area which is located along the southern boundary of the LLNL facility. No off site drinking water wells have had detectable concentrations of benzene and ground water remediation has greatly reduced the distribution and concentration of benzene (Happel et al. 1996). Although off site benzene concentrations did exceed comparison values in monitor wells, no drinking water wells have been or will be contaminated (due to ongoing groundwater remediation) and no exposure has or will occur and further evaluation of benzene exposure is not necessary.

Chomium-6 concentrations above the health comparison value (30 ppb) are limited to on site areas, the industrial properties northwest of LLNL, and a small area along Arroyo Seco. Well 11Q2 is the only well analyzed with chromium-6 values above the health comparison value (30 ppb; chromium-6 was also detected in wells 11J2 and 7D2). It should be noted that analyses of chromium-6 were not conducted for all wells. However, the 95th percentile value listed in Table 4 (75 ppb) and used in exposure dose calculations is greater than the highest value measured in well 11Q2. The maximum duration of exposure is 30 years based on the operating history of the LLNL facility. The pathway is complete only for past exposure; well 11Q2 and nearby residential wells were destroyed in the 1980s.

Past exposure to ground water contaminants was complete for chromium-6, PCE, and TCE for at least eight off site residential drinking water wells. The calculated exposure doses in Table 4 are health protective due to assumptions of exposure durations, ingestion rates, and other exposure factors. Similarly, the 95th percentile concentrations used in dose calculations are greater than measured values in any drinking water wells to account for uncertainty associated with potential contaminant concentrations prior to establishment of the ground water testing program. In addition to PCE and TCE, several other VOCs have been detected in off site wells (Table 3). Exposure doses for those VOCs were not calculated because the contaminants were not detected in drinking water wells, or if present, the concentrations were below health comparison or screening levels.

In addition to site-related contaminants, this evaluation of ground water data has found that several metals and nitrate are present throughout the Livermore Valley at concentrations above health comparison values. Past, current, and future exposure to these background metals or non-LLNL related contaminants is assumed to be complete due the widespread distribution of those contaminants and the common use of private drinking water wells. The completed exposure pathways to either site-related or background contaminants does not necessarily indicate that these exposures will cause sickness or disease. The public health implications of these exposures are evaluated in the following section.

Radionuclides in Ground Water

Ground water in the vicinity of LLNL has been monitored for a number of different radionuclides. These radionuclides, along with their measured concentrations and the number of analyses and detections are listed in Table 3. Most of the measured radionuclides were rarely detected or at background concentrations. Only Radon 222 had an off site concentration above the EPA-promulgated Maximum Contaminant Levels (300 pCi/L; proposed MCL). Uranium and its decay products, including radium, radon, lead (and other short-lived radionuclides) are naturally present in the substrate and ground water of the Livermore Valley. The single measured off site Radon value above the MCL occurred in a monitor well and probably represents normal background concentrations. Radon 222 in ground water in not considered a preliminary contaminant of concern. Tritium, which has been released by LLNL processes and accidents, is present as an on site ground water contaminant. All off site measurements of tritium are below the EPA MCL and do not appear to contain tritium from LLNL releases .

Ground Water Exposure Pathways

An off site well inventory that lists depths, screened intervals, completion and destruction dates, exposure potential, and usage is included in Appendix 5. Eighty-one wells are listed in this inventory. Many of these wells have been destroyed and are no longer potential points of exposure. Several of these wells are or were used for irrigation or livestock watering and are not used for domestic water supply. However, it is assumed that human exposure could occur at any well unless specific documentation of well usage indicates that such exposure is not likely (i.e., wells used exclusively as monitor or industrial supply wells).

The potential exposure doses to contaminants of concern are listed in Table 4 along with the exposed populations. The estimation of 95th percentile concentrations and exposure durations are described in Appendix 5 (Table A-1). Long term or lifetime exposure is assumed for all background contaminants. The background contaminants are widespread, but discontinuous, throughout the Livermore Valley depending on the sedimentological composition of the aquifers (Sorenson, *et.al*., 1985). Due to the common use of private water supply wells in this area, past, current, and future completed exposure pathways are assumed for the background contaminants.

The worst-case scenario for site-related contaminants assumes exposure durations of 30 years (1953 to 1983). PCE and TCE were detected in several private drinking water wells (as listed in Table 3) and a past exposure pathway was complete for those contaminants until provision of alternate water in 1983. Lesser exposure from volatization and dermal contact with contaminated well water may have continued until destruction of the affected wells in the late 1980s. Only one well (11R5/11R81) was potentially affected with the 95th percentile (worst-case) exposure concentration listed in Table 4. Measured PCE and TCE values in other affected wells were much lower.

Studies have shown that exposure to volatile compounds from routes other than direct ingestion may be as large as the exposure from ingestion alone. The inhalation dose due to volatization during a shower may equal the ingestion dose from 1.3 liters of water (Wan et.al. 1990) and that 50 -- 90% of VOCs in water may volatize during showering, laundering and other activities (Moya et.al. 1999; Giardino and Andelman, 1996). Similarly the dermal dose has been estimated to equal 30 % of the ingested dose (Maine DEP/DHS 1992). The PCE and TCE exposure doses in Table 4 include ingestion of contaminated water plus 70% of the ingestion dose due to inhalation plus 30% of the ingestion dose due to dermal contact.

Although benzene is present in off site wells at levels of concern, it has not been detected in drinking water wells. Off site benzene is very locally distributed along the southern boundary of LLNL and on SNL-L property. No residences or drinking water wells are located in this area and extensive remediation has restricted migration to other areas. The exposure pathway for benzene in groundwater was not and is currently not completed. Due to the limited distribution of benzene in ground water, further exposure assessment of benzene is not necessary.

Chomium-6 concentrations above the health comparison value (30 ppb) are limited to on site areas, the industrial properties northwest of LLNL, and a small area along Arroyo Seco (Appendix 5). Well 11Q2 is the only well analyzed with chromium-6 values above the health comparison value (30 ppb; chromium-6 was also detected in wells 11J2 and 7D2). It should be noted that analyses of chromium-6 were not conducted for all wells. However, the 95th percentile value listed in Table 4 (76 ppb) and used in exposure dose calculations is greater than the highest value measured in well 11Q2. The maximum duration of exposure is 30 years based on the operating history of the LLNL facility. The pathway is complete only for past exposure; well 11Q2 and nearby residential wells were destroyed in the 1980s.

Past exposure to ground water contaminants was complete for chromium-6, PCE, and TCE in at least 8 off site residential drinking water wells. The calculated exposure doses in Table 4 are health protective in estimating exposure durations, ingestion rates, and other exposure factors. Similarly, the 95th percentile concentrations used in dose calculations are greater than measured values in any drinking water wells to account for uncertainty associated with potential contaminant concentrations prior to establishment of the ground water testing program. In addition to PCE and TCE, several other VOCs have been detected in off site wells (Table 3). Exposure doses for those VOCs were not calculated because the contaminants were not detected in drinking water wells or if present, the concentrations were below health comparison values (CVs).

In addition to site-related contaminants, this evaluation of ground water data has found that several metals and nitrate are present throughout the Livermore Valley at concentrations above health comparison values. Past, current, and future exposure to these background metals or non-LLNL related contaminants is assumed to be complete due the widespread distribution of those contaminants and the common use of private drinking water wells. The completed exposure pathways to either site-related or background contaminants does not necessarily indicate that these exposures will cause sickness or disease. The public health implications of these exposures are evaluated in the following section.

Table 3. Detections and distributions of chemical (non-radiological) contaminants in ground water and identification of preliminary ground water contaminants of concern. Classification as a contaminant of concern indicates that additional evaluation is required but does not necessarily indicate that exposure has occurred.

Contaminants	CV (in ppb) CV Source	No. of Off site Detects > CV	Potable well detections > CV; No. wells sampled	Conc. Range (All Off site Wells; ppb)	Preliminary Contaminant of Concern (Y/N; Why?)
Arsenic	3 EMEGic	6	none; 6 wells sampled	4--53	No; Not detected in drinking water wells
Beryllium	20 EMEGcc	0	None; 6 wells sampled	ND	No; Not detected in drinking water wells
Boron	100 EMEGic	60	14B2,14B4, 14C2, 14C3, 14H1; 6 wells sampled	140--19,000	**Yes**
Cadmium	2 EMEGcc	2	none; 2 wells sampled	1--13	No; Not detected in drinking water wells
Chromium	100 MCL	80	11A1, 11Q2; 12 wells sampled	3--730	**Yes**
Chromium-6	30 RMEGc	27	none; 3 wells sampled	5--300	**Yes**
Lead	15 Action Level	5	none; 2 wells sampled	1--150	No; Not detected in drinking water wells
Manganese	50 RMEGc	25	none; 6 wells sampled	10--1,600	**Yes**
Nitrate	10,000 MCL	48	14B1; 1 well sampled	1,700--93,000	**Yes**
Silver	50 RMEGc	1	none; 8 wells sampled	7--80	No; single sample > CV not replicated
Benzene	1 CREG	39	none; 15 wells sampled	1--560	No: Off site detections in monitor wells only, no exposure

Table 3. Detections and distributions of chemical (non-radiological) contaminants in ground water and identification of preliminary ground water contaminants of concern. Classification as a contaminant of concern indicates that additional evaluation is required but does not necessarily indicate that exposure has occurred.

Contaminants	CV (in ppb) CV Source	No. of Off site Detects > CV	Potable well detections > CV; No. wells sampled	Conc. Range (All Off site Wells; ppb)	Preliminary Contaminant of Concern (Y/N; Why?)
Carbon Tetrachloride	70 EMEGic	0	none; 20 wells sampled	1--31	No: Off site detections less than CV
Chloroform	100 EMEGcc	0	none; 20 wells sampled	1--95	No: Off site detections less than CV
1,2-Dibromoethane	0.05 MCL	1	none; 0 wells sampled	10	No: Single monitor well detection not confirmed by subsequent analyses
1,1-Dichloroethane**	2,000 EMEGic	0	none; 19 wells sampled	1--44	No: Off site detections less than CV
1,2-Dichloroethane	2,000 EMEGic	0	none; 20 wells sampled	1--38	No: Off site detections less than CV
1,1-Dichloroethene	90 EMEGcc	0	none; 20 wells sampled	1--43	No: Off site detections less than CV
1,2-Dichloroethene	2,000 EMEGic	0	none; 20 wells sampled	1--30	No: Off site detections less than CV
Tetrachloroethylene (PCE)	5 MCL	499	4; 20 wells sampled	1--490	**Yes**
Trichloroethylene (TCE)	5 MCL	465	2; 20 wells sampled	1--2700	**Yes**

* ATSDR estimates are based on ingesting 2 liters of water per day by an adult. The concentrations were determined using ICRP 67 ingestion dose conversion factors for whole body, effective doses.
**No comparison value is available for 1,1-DCA, animal data suggest it is less toxic than 1,2-DCA so the 1,2-DCA value is used.

Table 3. Detections and distributions of radiological contaminants in ground water and identification of preliminary ground water contaminants of concern. Classification as a contaminant of concern indicates that additional evaluation is required but does not necessarily indicate that exposure has occurred.

Radionuclides	CV (in pCi/l); CV Source	No. of Off site Detects > CV	Potable well detections > CV; No. wells sampled	Conc. Range (All Off site Wells; pCi/L)	Preliminary Contaminant of Concern (Y/N; Why?)
Gross Alpha	15 pCi/L; MCL	0	none; 3	0.05--13	No; Off site detections less than CV
Gross Beta (for man-made radionuclides)	50 pCi/L; MCL	1	1; 4	0.8-- 201	No; Single analysis > CV, all other measurements << CV; note these samples are not wells, but are drinking water samples
Plutonium 238 Plutonium 239/240	ATSDR estimate* 6 pCi/L	0	None; none	ND	No; no off site detections, 2 on site detection < 1 pCi/L
Radium-226 + Radium 228	5 pCi/L; MCL	0	Ra 226 -- none; 2 Ra 228 -- none; 1	Ra 226 0.21 Ra 228 0.6--13	No; Single off site detection less than CV
Radon 222	300 pCi/L; proposed MCL	1	None; 1	30-- 400	No; single off site detection > CV, probably background
Thorium-228 (No existing MCL)	ATSDR estimate* 21 pCi/L*	0	none; 0	7	No; Single off site detection less than CV
Thorium-232 (No existing MCL)	ATSDR estimate* 7 pCi/L	0	none; 0	ND	No; No off site detections
Tritium (H-3)	20,000; MCL	0	none; 3	6.2--7920	No; Off site detections less than CV
Uranium-233/234 (No existing MCL)	ATSDR estimate* 30 pCi/L	0	none; 1	0.1--5.7	No; Off site detections less than CV

Table 3. Detections and distributions of radiological contaminants in ground water and identification of preliminary ground water contaminants of concern. Classification as a contaminant of concern indicates that additional evaluation is required but does not necessarily indicate that exposure has occurred.					
Radionuclides	CV (in pCi/l); CV Source	No. of Off site Detects > CV	Potable well detections > CV; No. wells sampled	Conc. Range (All Off site Wells; pCi/L)	Preliminary Contaminant of Concern (Y/N; Why?)
Uranium-235/236 (No existing MCL)	ATSDR estimate* 32 pCi/L	0	none; 1	0.04--0.3	No; Off site detections less than CV
Uranium-238	15 pCi/L (as alpha emitter)	0	none; 9	ND--2.5	No; Off site detections less than CV

EMEGic………Environmental Media Evaluation Guide, intermediate duration, child exposure and intake
EMEGcc………Environmental Media Evaluation Guide, chronic duration, child exposure and intake
MCL…………..Maximum Contaminant Limit
RMEGc…………Reference Dose Evaluation Guide, child exposure and intake
See Appendix 4 for the description and derivation of the comparison values.
*ATSDR Estimates of the maximum concentration in radionuclides in water are based on 2 L per day for a year, the MCL limit of 4 millirem per year, and Federal Guidance 13 dose coefficients (Cancer risk coefficients for environmental exposure to radionuclides).

Table 4. Estimated doses from ground water exposure for preliminary contaminants of concern.

Contaminant	**Pathway Status** **Duration**	**Concentration Geo-mean** **95th %**	**Exposed Population (Well ID)**	**Exposure Dose (95th %) mg/kg/day**
Benzene	Incomplete 30 years	31.6 ppb 1,034 ppb	not present in drinking water wells	No Exposure
Boron	Complete-- past, present, future; 70 years	732 ppb 3,097 ppb	Livermore Valley background	0.15 Child 0.08 Adult
Chromium	Complete-- past, present, future; 70 years	21.4 ppb 83 ppb	Livermore Valley background	0.005 Child 0.002 Adult
Chromium-6	Complete-- past; Max. 30 years	6.5 ppb 75 ppb	11Q2, 11J2, 7D2	0.002 Child 0.001 Adult
Manganese	Complete-- past, present, future; 70 years	137.5 ppb 2,009 ppb	Livermore Valley background	0.13 Child 0.07 Adult
Nitrate	Complete-- past, present, future; 70 years	21,318 ppb 80,120 ppb	Livermore Valley (Sorenson, *et.al*, 1985)	4.30 Child 2.30 Adult
PCE	Complete-- past; Max. 30 years	241 ppb 511 ppb	11J2, 11Q2/3, 11Q81, 11R81, 11R3/4	0.03 Adult *(0.05 Child; no children present at 11R5 location)*
TCE	Complete-- past, Max. 30 years	5.6 ppb 45 ppb	11J2, 11Q2/3, 11Q81, 11R81, 11R3/4	0.004 Child 0.002 Adult

Exposure Doses (ED) are calculated from the following equation:
ED= (Contaminant Concentration x Ingestion Rate x Exposure Factor)/ Body Weight
Estimation of 95th Percentile concentrations and durations are described in Appendix 5.
Ingestion rates are 2 liters/day for adults or 1liter/day for children
Exposure Factor is the percentage of intake from contaminated source; most conservative value of 100% is used.
Body weights are lognormal distributions around 72 kg for adults or 19.7 kg for children.
PCE and TCE ingestion doses are increased by a factor of 2 to account for inhalation and dermal contact.

Soil and Sediment

Background

Radiological and chemical contaminants are present in the soils and sediments* within and adjacent to the LLNL site as a result of facility operations, accidental releases, and waste disposal activities. LLNL has conducted annual soil and sediment sampling activities since 1971. Monitoring and assessment of soil and sediment has emphasized the estimation and inventory of the potential long-term buildup of radionuclides in the environment (Harrach et al. 1996) and characterization and remediation of areas of on site contamination (Thorpe et al. 1990). This evaluation will focus on potential contamination and exposures in off site areas.

The remainder of this background section will briefly review the available data as they relate to the distribution and migration of soil and sediment contaminants. The following sections will document the scope and conclusions of past soil and sediment studies relative to sources of LLNL soil and sediment contamination, identify those contaminants that occur in areas of off site exposure at levels of health concern, and determine whether the potential exposures occurred in the past, may be presently occurring, or may occur in the future.

LLNL collects and analyzes annual soil and sediment samples from a number of on and off site locations. The locations and results of these analyses are presented in the annual Environmental Reports (LLNL various years). In addition to this annual sampling program, LLNL has also conducted several focused sampling programs which include, an assessment of organic solvent concentrations in soil (Carpenter 1984), sampling associated with the LLNL-site remedial investigation (Thorpe et al. 1990), and the previously described radiological assessment of Big Trees Park (Mac Queen 1995; Mac Queen et al. 2002). Other site-specific soil evaluations have been conducted by the EPA (EPA 1994a; 1995) and by the State of California (CDHS 1980).

Both the CDHS 1980 study and a study by Gallegos (1995) evaluated radionuclide concentrations in soil samples downwind of the LLNL facility. Both studies indicate that plutonium concentrations on and immediately downwind (local winds are predominately from the west and southwest) of the LLNL facility are elevated relative to background concentrations. Although background plutonium concentrations occur beyond distances of 100 to 500 meters from the facility fence, these reports do indicate some airborne deposition of plutonium in soil. Although the off site plutonium concentrations are well below health protective screening levels, the off site plutonium concentrations and distributions are evaluated in the following sections.

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*Sediment is defined as finely divided solid materials that have settled out of a stream, drainage system, or standing water. Soil is composed of similar geological materials, which may or may not exhibit an active soil profile, but is not currently located in an aquatic environment.

The soil and sediment data were obtained via electronic transfer of the LLNL environmental data base in 1998 (and updated in 2003) and from a number of written documents. The electronic data set included more than 30,000 records of soil and sediment analyses of 230 chemical and radiological parameters. The data set includes sample results from the years 1987 to 2003. Data from earlier years are derived from written reports and will be referenced as appropriate. In general, the available data appear adequate for assessing potential exposures. Data gaps or limitations will be discussed relative to specific contaminant sources or exposure pathways as necessary.

Soil and sediment samples are collected and analyzed according to standardized procedures, although some procedures have changed over time depending on the specific objectives of different studies (Tate et al. 1999). Soil analyses are organized in three depth ranges (0 to 3 inches; 3 to 12 inches; and greater than 12 inches) plus results from an unspecified depth. Annual soil and sediment samples are typically collected from the top 3 inches. As a conservative approach for this assessment, all samples from an unspecified depth are assumed to be surface soils with the highest potential for human exposure.

Soil and Sediment Contaminant Sources

Soil and sediment contamination at LLNL has resulted primarily from the deposition of airborne emissions, leaks and spills, storm water runoff, and waste discharges to the sewer system. The distribution of processed sewage sludge to homeowners is a specific concern that will be evaluated in this section. In addition to these indirect sources of soil and sediment contamination, historic waste disposal activities, including operations of the naval air station occupying the site before LLNL, have resulted in areas of residual on site soil contamination. The potential sources of radiological and chemical contamination to off site soil and sediment at LLNL are directly reflected by the scope of the studies and reports, which have sought to document and quantify those sources.

Annual evaluations of surface soils at locations around the LLNL site boundary and throughout the Livermore Valley began in 1971 (LLNL Environmental Reports). The primary emphasis in these analyses has been to determine background activities and possible accumulations of plutonium and other gamma emitting radionuclides. Although there have been some changes in sample locations and the addition of parameters, such as naturally occurring radionuclides (i.e., K 40 and Th 232) and Cs 137 from atmospheric fallout, these annual samples provide a long term framework for assessing potential radiologic releases from the LLNL facility.

There are no known direct off site releases of contaminated soil or sediment from LLNL process or waste disposal activities. Each of the contaminant sources listed in Table 5 is the result of an on site release followed by an intermediate process, such as migration via air or water to an off site area of potential community exposure. While the original sources are related to on site emission sources such as air release stacks or storm water drains, the areas of resulting soil or sediment contamination are determined by the intermediate transport process. Consequently, releases to air result in downwind soil contamination east and northeast of the facility and releases to surface or ground water result in soil contamination west and northwest of the facility. Releases to the sewage system, which may disperse throughout the down-gradient system, are concentrated in the sludge and effluent at the Livermore Water Treatment Plant with subsequent sludge distribution throughout the Livermore Valley (ATSDR 2003d).

Table 5. Sources of soil and sediment contamination and available information.

Soil or Sediment Contaminant Source	**Contaminant(s)**	**Data available and related studies or reports**
<u>Air Transport</u> Deposition to soil from airborne tritium releases a) chronic b) acute	Tritium (H 3)	LLNL Annual Environmental Reports; ATSDR Health Consultation (2002) and PHA (2003c).
Deposition to off site soil from re-suspension of on site contaminants	Pu 239/240	LLNL Annual Environmental Reports; Lindeken et al. 1973; CDHS 1980; Gallegos, 1995a.
Airborne re-suspension of soils contaminated by leachate from on site landfills and other waste disposal activities	VOCs, metals, and radionuclides	Buerer A. 1983; Carpenter 1984; CERCLA Remedial Investigations Report (Thorpe et al. 1990);
<u>Water Transport</u> Sediment deposition from surface water runoff to storm water system	Pu 239, Tritium, other gamma-emitting radionuclides, heavy metals, VOCs, and pesticides	LLNL Annual Environmental Reports; Surface water discharges regulated by permit; Gallegos 1995b.
Soils contaminated by ground water from leaks and spills of VOCs and petroleum products to surface and subsurface soils	TCE, PCE, petroleum products (gasoline, kerosene, jet fuel), benzene (and other hydrocarbon constituents)	Carpenter 1984; CERCLA Remedial Investigations Report (Thorpe et al. 1990); Iovenitti et.al. 1991;

Table 5. Sources of soil and sediment contamination and available information.		
Soil or Sediment Contaminant Source	**Contaminant(s)**	**Data available and related studies or reports**
Sewered Water Transport Discharges to sewer system a) chronic b) acute	Tritium, Cs 137, Pu 239, and Am 241 (also gross alpha and beta); nine metals, cyanide, and total toxic organics	Regulated by permit; LLNL Annual Environmental Reports; Special studies-- 1) Bennett and Rich 1967; 2) Myers et.al. 1976; 3) Balke 1993; 4) ATSDR Health Consultations 1999b, 2000; 5) Mac Queen 2002; 6). ATSDR PHA 2003d.

Soil and Sediment Preliminary Contaminants of Concern

Thirty-five non-radiologic soil or sediment contaminants have been detected on or adjacent to the LLNL facility. These contaminants, along with their maximum values, and respective screening values are listed in Tables 6. Twenty-four of the 35 metals or compounds were detected at concentrations below screening values and do not require further evaluation (Table 6). The potential for beryllium contamination has been identified as a specific community concern. The beryllium soil measurements were all more than 20 times lower than its soil comparison value (100 ppm) and represent natural or background concentrations.

Eleven non-radiologic contaminants were detected at concentrations greater than their respective screening values (Table 7; aldrin, benzo(a)pyrene, benzo(b)fluoranthene, cadmium, chromium, dieldrin, lead, mercury, N-nitroso-dimethylamine, PCBs, and vinyl chloride). Table 7 shows that the distribution of the 11 contaminants with concentrations greater than their respective CVs is restricted to areas within the LLNL storm water system. As none of these contaminants are present in areas of potential community (off site) exposures at concentrations above their CVs, they are not considered preliminary contaminants of concern in soil or sediment.

Table 6. Soil and sediment contaminants detected on or adjacent to LLNL. These contaminants are not considered as preliminary contaminants of concern because concentrations are below screening levels or due to the lack of potential off site exposures (**contaminants in bold** have concentrations > CVs, but are not present in areas of potential exposure; Table 7).			
Contaminant	**Maximum Value mg/kg (ppm)**	**CV (ppm)**	**Selected as Preliminary Contaminant of Concern; Reason**
Aldrin	0.14	0.04 CREG	No; Single detection in storm drain system; no exposure
Antimony	13	20 RMEG--cc	No; Max. values < CV
Arsenic	14	20 RMEG--cc	No; Max. values < CV
Barium	330	4000 RMEG--cc	No; Max. values < CV
Benzo(a)anthracene	0.9	0.9 EPA SL	No; Single detection not greater than CV
Benzo(a)pyrene	0.7	0.1 CREG	No; Two detections in storm drain system; no exposure
Benzo(b)fluoranthene	1.5	0.9 EPA SL	No; Two detections in storm drain system; no exposure
Benzo(ghi)perylene	0.6	NA	No; 2 detections in storm drain system; no exposure
Benzo(k)fluoranthene	1.5	9 EPA SL	No; Max. value < CV
Beryllium	4	100 EMEG--cc	No; Max. values < CV
Bis(2-chloroethyl)ether	0.03	0.6 CREG	No; Max. value < CV.
Cadmium	23	10 EMEG--cc	No; Single detection > CV in on site location; no exposure
Chloromethane	0.002	85 EPA SL	No; Max. value < CV
Chromium	1500; 340	200 RMEG--cc (Cr-6)	No; two samples > CV ; both on site; no off site exposure
Chrysene	2.0	88 EPA SL	No; Max. value < CV
Dieldrin	0.14	0.04 CREG	No; Two on site detections > CV; no exposure
Dimethysulfide	0.03	NA	No; Single detection in storm drain system; no exposure
Endosulfan II	0.12	100 EMEG--cc	No; Max. value < CV

Table 6. Soil and sediment contaminants detected on or adjacent to LLNL. These contaminants are not considered as preliminary contaminants of concern because concentrations are below screening levels or due to the lack of potential off site exposures (**contaminants in bold** have concentrations > CVs, but are not present in areas of potential exposure; Table 7).

Contaminant	Maximum Value mg/kg (ppm)	CV (ppm)	Selected as Preliminary Contaminant of Concern; Reason
Endosulfan, alpha	0.03	100 EMEG--cc	No; Max. value < CV
Endrin aldehyde	0.003	20 EMEG--C-p	No; Max. value < CV
Lead	1700	400 EPA SL	No; One sample > CV at on site location, no exposure
Mercury, metallic	38	23 EPA SL	No; One sample > CV in storm drain system; no exposure
Molybdenum	15	300 RMEG--cc	No; Max. value < CV; no exposure
N-nitrodimethylamine	0.03	0.0005	No; Single detection in storm drain system; no exposure
PCBs Arochlor 1254/60	1.3	0.4 CREG	No; 3 samples > CV in storm drain system; no exposure
O-xylene	0.16	100000 EMEG--ic	No; Max. value < CV
Tetrachloroethylene	0.37	12 EPA SL	No; Max. value < CV
Trichloroethylene	3	58 EPA SL	No; Max. value < CV
Vanadium	61	550 EPA SL	No; Max. value < CV
Vinyl chloride	280	0.5 CREG	No; One sample > CV in storm drain system; no exposure
Zinc	3000	20000 EMEG--cc	No; Max. value< CV; no exposure

CREG…….. Cancer Risk Evaluation Guide
EMEG--cc…. Environmental Media Evaluation Guide, chronic duration, child exposure
EMEG--ic…..Environmental Media Evaluation Guide, intermediate duration, child exposure
EPA SL…….EPA Screening Level
RMEG--cc…..Reference Dose Evaluation Guide, chronic duration, child exposure
The derivation of the above comparison values (CVs) is presented in Appendix 4.

Table 7. Sediment stations with contaminant concentrations greater than their respective comparison values. Sample concentrations and station locations are from: Gallegos (1995b), Thorpe (et al. 1990), or the LLNL Environmental Data Base (1998; 2003).			
Contaminant	**Concentration mg/kg (ppm)**	**Station(s) > CV**	**Location(s)**
Aldrin	0.14	SD-MH11OG-93	– manhole in storm drains
Benzo(a)pyrene	0.7 0.5	SD-MH11OG-93 SSS-009	– man-hole in storm drains – next to B-514 yard
Benzo(b) fluoranthene	1.5 1.0	SD-CB320F-17 SSS-009	– catchment basin in storm drains – next to B-514 yard
Cadmium	10 14 13 10 10 22 11 10 12 10 10 23	SD-OCS-530-1 SD-BS-6-6 SD-BS-4-6 SD-BS-7-6 SD-CB260G-3 SD-CB320F-17 SD-CB610A-5 SD-MH110G-9 SD-OCS-190- SD-OCS-610-1 SD-OCS-690-1 SSS-009	– open channel storm drains – Arroyo Seco – adjacent to Patterson Pass Rd. – East Ave. and Arroyo Seco – catchment basin in storm drains. – catchment basin in storm drains. – catchment basin in storm drains. – manhole in storm drains. – open channel in storm drains. – open channel in storm drains. – open channel in storm drains. – next to B-514 yard
Chromium	340 1500	SD-CB310C-2 SSS-009	– catchment basin in storm drains. – next to B-514 yard
Dieldrin	0.14 0.07	SD-BS-6-6 SD-CB-410E-044	– Arroyo Seco – catchment basin in storm drains.
Lead	1700 570 400	141-R3U1 SD-CB320F-1 SD-CB420F-2	– Building 141 drain – catchment basin in storm drains. – catchment basin in storm drains.
Mercury, metallic	38	SD-CB420F-2	– catchment basin in storm drains.
N-nitroso-dimethylamine	0.03	SD-OCS-190-3	– open channel in storm drains.
PCBs Arochlor 1254/60	1.3 0.7 0.7	SSD-008 SSD-009 SSS-009	– storm drain at old solar ponds – storm drain next to B-514 yard – next to B-514 yard

Table 7. Sediment stations with contaminant concentrations greater than their respective comparison values. Sample concentrations and station locations are from: Gallegos (1995b), Thorpe (et al. 1990), or the LLNL Environmental Data Base (1998; 2003).			
Contaminant	**Concentration mg/kg (ppm)**	**Station(s) > CV**	**Location(s)**
Vinyl chloride	280	SD-CB320F-17	– catchment basin in storm drain sys.

Radionuclides in Off Site Soil and Sediment

The potential distribution of tritium in soil due to several accidental tritium releases has been evaluated in a previous PHA (ATSDR 2003c). This evaluation concluded that airborne tritium releases in 1965 and 1970 resulted in short term increases in tritium exposure via deposition to soil for residents of the areas to the east and northeast of the LLNL facility. These exposures were short-term and unlikely to cause any adverse health effects. Tritium in soil due to chronic releases was also evaluated in a previous health consultation (ATSDR 2002) and included in the estimation of total tritium doses (ATSDR 2003c).

Similarly, potential community exposure to Pu 239 (and associated radionuclides*) released to the Livermore sewer system and distributed to the Livermore community via processed sewage sludge was also evaluated in a PHA (ATSDR 2003d). Based on estimated maximum Pu 239 concentrations in sewage sludge, exposures to the public or LWRP workers are also unlikely to cause any adverse health effects. The potential for these separate soil pathways to contribute to cumulative radiologic doses is addressed in the following section on Public Health Implications.

Surveillance monitoring of soils by LLNL (summarized by Gallegos 1995a and in the annual Environmental Reports) and a Pu soil study by the CDHS (1980) have indicated elevated soil

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* Plutonium will be present as several different isotopes. Typical weapons grade plutonium consists of about 94% Pu 239 and about 6% Pu 240 with much lower percentages of Pu 238, 241, and 242 (NAS 1995). Standard analyses using alpha spectroscopy will not differentiate between Pu 239 and Pu 240. However the dose conversions factors for the Pu 239 and Pu 240 isotopes are equal so that differences in the relative abundance will not change the resulting dose estimates. Due to the much higher proportion of Pu 239, this document will refer to combined Pu 239/240 measurements as Pu 239. The releases may also have contained an unknown proportion of Am 241. In typical weapons-grade plutonium, Am 241 comprises less than 1 % of the activity (NAS 1995) and does not have a significant contribution in the resulting dose. This assessment will focus on Pu 239 as the primary dose constituent.

concentrations of Pu 239 and Pu 239/240 in the immediate downwind areas adjacent to the LLNL facility. Samples from distances of 500 m or less from the northern to eastern boundaries of the LLNL fence line have concentrations of Pu 239 (or Pu 239/240) that are elevated above background levels. These analyses also indicated that downwind soil concentrations of Cs 137, U 238, and Th 232 are not elevated with respect to upwind or background stations.

NCRP Report 129 (1999) has established "Recommended Screening Limits for Contaminated Surface Soil…" Assuming a residential exposure scenario, which includes a home garden, the screening limit for Pu 239 and Pu 240 is 32 pCi/g and for Pu 238 the limit is 35 pCi/g (Table 8). According to the NCRP, "If the surface soil concentration is below the suggested limits, then no further action will generally be required." Although all measured plutonium soil concentrations are below the NCRP screening limits, due to community concern, these radionuclides in soil will be further evaluated by calculation of potential doses.

For areas downwind of the LLNL Facility, the maximum Pu 239 soil concentrations, as determined by either the CDHS or by LLNL, is 0.0312 pCi/g (the maximum Pu 238 concentration is 0.0036 pCi/g). As these maximum concentrations are more than 1000 times lower than NCRP screening limits (32 and 35 pCi/g, respectively[*]), no further action regarding soil contamination of the area immediately downwind of the LLNL facility is necessary. However, because this area of potential exposure was also affected by the accidental tritium releases of 1965 and 1970 (ATSDR 2003c), the potential for cumulative doses to ionizing radiation will be further evaluated in the following section on Public Health Implications.

Although soils adjacent to the LLNL eastern and northern boundaries have Pu concentrations above background, none of these samples exceeded the NCRP soil screening values (NCRP 1999). The only off site radionuclides in soil or sediment samples which exceeded the screening limits were radium 226 and 228†. Most radium analyses, including background stations, exceeded the screening limits but there is no indication that any stations exceeded background values. All radiologic doses calculated in this PHA do not include estimates of background.

Surveillance monitoring of sediment from the Arroyos and the LLNL storm water system have

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* In a more detailed site-specific analysis of Pu 239 concentrations in sewage sludge, ATSDR determined that a soil concentration of 816 pCi/g would be required to produce a dose that exceeds the ATSDR MRL of 100 mrem/year. Both derived concentrations are protective of public health but based on different exposure scenarios and dose limits with the NCRP screening limit based on a much greater percentage of time on site and outdoors and a dose limit of 25 mrem/year.

† From NCRP 129 (1999): "The recommended screening values for some land use scenarios are less than the average US background and thus may be indistinguishable from background. If so, more intensive soil sampling and analysis may be needed."

also detected isolated locations of elevated Pu 239 concentrations at the storm water outfalls in the Arroyos. The maximum Pu 239 sediment concentration in an off site location was a station from Arroyo Las Positas with a maximum concentration of 0.06 pCi/g. On site sediment samples from the storm water system had a maximum concentration of 0.17 pCi/g. As with the off site soil samples, none of the off site sediment samples approach the NCRP soil screening limits and are below levels of public health hazard. Plutonium 239 (Pu 239) is also identified as specific contaminant of concern. Although Pu 239 has not been detected in soils or sediments in areas of potential off site exposure at concentrations of public health hazard, the off site distributions and potential exposure doses will be evaluated due to community concern about this issue.

Table 8. Surface soil screening limits for a suburban residential exposure (NCRP 1999).

nuclide	Am 241	Cs 137	Co 60	Pu 238	Pu 239	**Ra 226**	**Ra 228**	Th 228	U 238	U 235
Surface soil screening limits (pCi/g)										
	32.4	5.4	1.2	35.1	32.4	0.15	0.21	1.3	56.7	12.2
Maximum off site soil concentrations (pCi/g)										
	0.23	0.42	0.21	0.13	2.96[a]	1.27[b]	0.88[b]	1.01[b]	1.14[a]	0.92[b]
Maximum off site sediment concentrations (pCi/g)										
	--	0.04	--	0.01	0.06	0.92	0.95	0.80	0.68	0.61

[a]This value is from the Livermore Water Treatment Plant.
[b]Background location; Most of the Ra 226 and Ra 228 soil concentrations exceeded the screening limits due to background distribution of radium isotopes.

Soil and Sediment Exposure Pathways

The concentrations and locations of the eleven sediment contaminants with measured concentrations greater than their respective CVs are listed in Table 7. Most of the contaminant detections greater than a comparison value are found in sediment samples within the LLNL storm drain system, with the remainder occurring in sediments of on site catchment basins or outfalls. It is also significant that 4 of the 11 contaminants had only one detection greater than a chronic or long-term comparison value and four others had only two detections greater than comparison values. No community exposures are likely to occur for on site sediments within the LLNL storm drain system.

Of the these 11 soil and sediment non-radiologic contaminants, only dieldrin and cadmium had detections above their respective comparison values in areas of potential community exposure (Table 7; note that the stations SD-BS-6-6 and SD-BS-4-6 are identified as background locations; Gallegos, 1995b). These locations are, for cadmium- in Arroyo Seco and adjacent to Patterson Pass Rd., and for dieldrin-- in Arroyo Seco. Multiple sample locations for each of these contaminants are present in each of those areas.

It is important to point out that the comparison values used for preliminary screening of contaminants of concern assume that the contaminant is present in the soil of a residential yard and that exposure occurs continuously (Appendix 4). Although the pathway of exposure to cadmium and dieldrin are potentially complete, the areas of potential exposure were in Arroyo sediments or along roadways, which for which exposure would occur infrequently. When such infrequent exposure is factored into the determination of contaminants of concern, neither cadmium nor dieldrin in soil or sediment are present at concentrations of public health concern. Consequently, there are no completed pathways of exposure for non-radiologic contaminants of concern for the soil and sediment pathway.

Exposures to radiologically-contaminated soil or sediment from the historic accidental tritium releases or from Pu 239-contaminated sludge have been evaluated in previous evaluations (ATSDR 2002, 2003c, 2003d). Although the completed or potentially completed exposures for those sources and areas of soil contamination are below levels of public health concern, the public health implications section will further evaluate the potential for cumulative exposures across multiple pathways. For the purpose of evaluating potential cumulative exposures and doses and due to community concerns, tritium and Pu 239* are considered contaminants of concern for the soil pathway and will be further evaluated in the following section on Public Health Implications.

Surface Water

Background

Two westward flowing surface water streams historically crossed the LLNL site, Arroyo Las Positas along the northern portion of the site and Arroyo Seco in the southern portion of the site. These intermittent streams have been channelized and/or relocated to the northern and southern boundaries of the site, respectively, and incorporated into the storm water management system of the facility (Thorpe et al. 1990). The historical relocation of these streams and the evolution of the LLNL storm water management system are discussed in the LLNL CERCLA Remedial Investigations Report (Thorpe et al. 1990) and not repeated in this PHA.

A shallow pond (Drainage Retention Basin) was excavated in the central portion of the site beginning in 1972 (with further excavation and lining in 1992; Gallegos 2001) for purposes of flood control and retention of storm water runoff. Currently, there is an extensive storm water management system that incorporates the drainage basin (lined to prevent infiltration), open and culverted channels and ditches, and outfalls into the Arroyos. Storm water discharge via the

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* Note that dose calculations for potential exposures to Pu 239 include cumulative doses from the radionuclides that may be associated with Pu 239, such as Pu 238, 240, 241, and 242.

outfalls into the Arroyos is currently regulated by permit with extensive water quality monitoring.

This portion of the Livermore Valley is an area of groundwater recharge such that surface water typically infiltrates downward into the underlying shallow groundwater flow system. Both Arroyo Seco and Arroyo Los Positas are intermittent streams that flow only during and after rainfall events, particularly during the winter rainy season. Seasonal surface water flows that do not enter the groundwater flow system ultimately enter San Francisco Bay via Alameda Creek. Neither Arroyo Seco nor Arroyo Las Positas are used as sources of drinking water and based on the extent of channelization and access limitations have very limited recreational use.

The South Bay Aqueduct, which is part of the California Water Project, flows in a southwesterly direction across Alameda County and passes about 300 m (1,000 ft) southeast of the southeastern corner of the LLNL facility. The South Bay Aqueduct, which conveys drinking water for much of the greater San Francisco Bay area (including the Livermore area), is an open lined canal in the area adjacent to the LLNL facility. The South Bay Aqueduct is up-gradient of the LLNL facility with respect to both surface and groundwater flow directions.

Surface Water Contaminant Sources

There is a large number of historical and current contaminant sources on the LLNL facility. These sources are explicitly documented in the 1990 CERCLA Remedial Investigations Report (Thorpe et al. 1990) and in the annual Environmental Reports (LLNL 1960--2001, various titles, all listed by senior author under LLNL). However, as the LLNL facility is in an area of groundwater recharge with very limited and intermittent surface water runoff, there is little potential for most of these on site contaminant sources to significantly affect the off site surface water bodies. Consequently, the most important sources of contamination for the surface waters are the permitted outfalls in the Arroyos and direct storm water runoff into the Drainage Retention Basin. There is no direct hydrologic connection from the LLNL facility to the South Bay Aqueduct, such that the only potential source of contamination for that water body is indirect releases to the atmosphere and subsequent deposition (of particulates or rainwater) within the open channel portion of the Aqueduct.

Contaminant monitoring of the surface waters are conducted at several locations on and adjacent to the LLNL facility. Sampling stations are located in the Arroyos both upstream and downstream of the LLNL facility and also include several rain sampling stations. Surface waters, including rain, are sampled for a complete suite of chemical and radiological constituents. Sampling locations and analytical quality assurance of surface waters appear to be adequate for the purpose of public health assessment.

Surface Water Preliminary Contaminants of Concern

Environmental sampling of surface water by LLNL is oriented towards quantification of the contaminant concentrations in storm water runoff and compliance with related permits (National Pollutant Discharge Elimination System; NPDES). LLNL also follows DOE requirements related to storm water monitoring for radiological effluent (Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance [DOE 1991] and applicable portions of DOE Orders 5400.1 [General Environmental Protection Program] and 5400.5 [Radiation Protection of the Public and the Environment].

Surface water sampling locations include stations on the Arroyos (Seco and Las Positas) at the storm water discharge outfall locations, additional stations upstream and downstream of the outfalls, influent and effluent locations for the Drainage Retention Basin, and other on site locations associated with individual on site buildings. Additional radiologic sampling stations are located at seven locations throughout the area including the LLNL swimming pool and the Lake Del Valle and Calaveras reservoirs (Biermann 2001).

The following evaluation of surface water contaminants of concern is based on sampling data from the LLNL database which was electronically transmitted to ATSDR in 1998 and updated in 2003. The surface water database contains 73,380 records for 205 non-radiologic compounds or elements and 5,721 records for 17 radiological parameters. The electronic database covering the years from 1985 to 2003 was supplemented by reference to the published annual environmental reports which date from 1959 to 2003 (LLNL , various authors, 1959--2003).

Table 9 lists the non-radiological and radiological surface water contaminants detected at either on site or off site locations at concentrations greater than drinking water comparison values (CVs; Appendix 4). Most surface water monitoring locations are on site. The flow direction at these stations may be influent (onto the LLNL facility) or effluent (flowing off site). For purposes of this evaluation, effluent stations are considered off site because the stations are on the facility boundary and the direction of flow is off site. Water from influent locations flows into the LLNL storm water system such that no off site exposure is possible. Of the 25 non-radiologic surface water contaminants listed in Table 9, only boron, lead, manganese, and nitrate have been consistently detected above drinking water comparison values at locations of potential off site exposure.

Boron, lead, manganese, and nitrate, are considered to be preliminary contaminants of concern for the surface water pathway. Also, due to community concerns about potential exposures to tritium and Pu 239, these radionuclides are also considered preliminary contaminants of concern. Potential community exposures to these surface water contaminants will be further evaluated in the following section on Surface Water Exposure Pathways.

Table 9. Concentrations, detections, and drinking water CVs for surface water contaminants. See Appendix 4 for a description of the various CVs and their derivation.

Contaminant	No. Analyses / No. Detections	Concentration Range (ppb)	Drinking Water Comparison value (ppb); CV Source	Preliminary Contaminant of Concern: Reason
1,1-Dichloroethane	361 / 3	0.5 – 5	No C.V. avail.	No: Limited exposure, infrequent detections at low concentrations
2,4- Dinitrophenol	296 / 1	23	20; RMEGcc	No: Single on site detection, no exposure
Acetone	262 / 42	5.2 – 2,900	20,000; RMEGic	No: Below CV
Antimony	477 / 15	5 – 1,500	6; MCL	No: Single on site detection > CV
Arsenic	703 / 373	1.9 – 780	10; MCL 23 samples > CV	No: Highest effluent location (L-ALPW) 60 ppb, single sample > CV
Barium	686 / 480	13 – 9,000	2,000; MCL	No: Only 2 samples > CV
Beryllium	737 / 72	0.2 – 860	4; MCL	No: Only 2 samples > CV, both on site (no exposure)
Boron	**468 / 398**	**50 – 21,000**	**100; EMEGic** **347 samples > CV**	**Yes: multiple detections > CV, also COC for ground water**
Bromacil	186 / 109	0.5 – 6,900	3,000; CLHA	No: single sample > CV at influent location (L-GRNE)
Cadmium	709 / 104	0.5 – 950	5; MCL 6 samples > CV	No: all samples > CV on site
Chloroform	363 / 18	0.28 – 120	80; MCL 5 samples > CV	No: all samples > CV on site
Chromium	694 / 451	0.9 – 1,600	200; CLHA	No: 2 samples > CV, both on site

Table 9. Concentrations, detections, and drinking water CVs for surface water contaminants. See Appendix 4 for a description of the various CVs and their derivation.

Contaminant	No. Analyses / No. Detections	Concentration Range (ppb)	Drinking Water Comparison value (ppb); CV Source	Preliminary Contaminant of Concern: Reason
Chromium-6	353 / 198	2 – 93	30; RMEGcc 3 samples > CV	No: 3 samples > CV, all on site or at influent locations
Cobalt	428 / 6	11 – 400	100; EMEGic 2 samples > CV	No: single sample > CV at effluent location
Copper	834 / 565	1 – 40,000	300; EMEGic 17 samples > CV	No: highest effluent location (L-ALPW) 850 ppb, single sample > CV
Diazinon	184 / 6	0.24 – 4.8	2; EMEGic 1 sample > CV	No: single sample > CV at influent location
Diuron	192 / 114	0.3 – 5,300	300; CLHA 3 samples > CV	No: only 3 samples > CV and all are at influent location (L-GRNE)
Lead	**720 / 225**	**1 – 2,700**	**15; Action Level 46 samples > CV**	**Yes: highest effluent location (L-ASW) 64 ppb**
Manganese	**796 / 544**	**8.3 – 30,000**	**500; RMEGcc 37 samples > CV**	**Yes: highest effluent location (L-ASW) 1,300 ppb**
Molybdenum	428 / 24	2.7 – 650	50; RMEGcc 9 samples > CV	No: single effluent location (L-ASW) 64 ppb > CV, all others > CV on site
Nickel	827 / 434	2 – 16,400	500; CLHA 4 samples > CV	No: only 2 samples > CV at effluent locations, max. conc. 630 ppb
Nitrate	**557 / 513**	**400-- 69,000**	**10,000; MCL 93 > CV**	**Yes: highest effluent location (L-WPDC) 19,000 ppb**
Selenium	702 / 22	1 – 650	50; MCL 2 samples > CV	No: only 2 samples > CV, both on site

Table 9. Concentrations, detections, and drinking water CVs for surface water contaminants. See Appendix 4 for a description of the various CVs and their derivation.

Contaminant	**No. Analyses / No. Detections**	**Concentration Range (ppb)**	**Drinking Water Comparison value (ppb); CV Source**	**Preliminary Contaminant of Concern: Reason**
Silver	701 / 23	0.5 – 5,700	50; RMEGcc 2 samples > CV	No: only 2 samples > CV, both on site
Simazine	199 / 48	0.2 – 80	50; RMEGcc 2 samples > CV	No: only 2 samples > CV, 1 influent, 1 effluent

Table 9. Concentrations, detections, and drinking water CVs for surface water contaminants. See Appendix 4 for a description of the various CVs and their derivation.

Radiologic Parameters	**No. Analyses / No. Detections**	**Concentration Range (pCi/L)**	**Drinking Water Comparison value (pCi/L); CV Source**	**Preliminary Contaminant of Concern: Reason**
Gross Alpha	1,183 / 345	0.014 – 226	15; MCL 16 samples > CV	No: Although both gross alpha and beta detections > CVs; isotope-specific doses are calculated in lieu of gross alpha and beta doses.
Gross Beta	1,190 / 658	0.3 – 262	50; MCL 11 samples > CV	
Plutonium 238	68 / 1	0.0086	N/A	No: single detection at effluent location (L-ASW), 33 non-detects.
Plutonium 239, 239/240	68 / 3	0.0018 – 0.0086	N/A	**Yes**: isolated detections at L-ASW and L-WPDC were not repeated in 65 other analyses at these same locations. Community concern.
Radium 226, 228	9 / 2	1.5 – 2	5; MCL	No: all detections < CV
Tritium	3,177 / 2,232	6.17 – 1,110,000	20,000; MCL 20 samples > CV	**Yes**: High values at on site buildings, only 1 off site storm water sample > CV (L-ALPN; 35,000 pCi/L), all other off site samples < CV including 44 other samples at L-ALPN.

Surface Water Exposure Pathways

Surface waters directly affected by contaminants released from the LLNL facility are not used as sources of drinking water by the Livermore community. Water from the South Bay Aqueduct, which is used for drinking water, is up-gradient of the LLNL facility and has no direct hydrological connection with LLNL discharges or storm water runoff. Also, there are no significant recreational facilities on either Arroyo Seco or Arroyo Las Positas, such that exposure via swimming or other recreational activities is very limited. Consequently, community exposures to surface waters affected by LLNL contaminant releases are limited to incidental recreational use by children playing in the Arroyos, or intermittent exposure by maintenance workers.

These potential exposures could present very limited and infrequent accidental ingestion and dermal contact with surface water. However, for the preliminary contaminants of concern listed in Table 9 there are no appropriate short term comparison values for use in evaluating this type of accidental exposure. The drinking water comparison values, as listed in Table 9, are based on daily exposure and ingestion of 2 L of water per day (or 14 L per week). Table 10 lists the surface water contaminants detected above CVs from Table 9 along with the maximum concentration measured in an area of potential exposure and the doses adjusted to account for intermittent or short term exposures based on incidental ingestion of 0.5 L/week.

It should also be pointed out that the storm water sampling program is designed to capture maximum contaminant loads by sampling immediately after or during rainfall events (Biermann 2001). Consequently, these maximum values do not represent normal or average conditions and provide health protective estimates of potential exposure. For example, Pu 239 (maximum concentration of 0.0018 pCi/L at L-WPDC) was analyzed 31 times at this same location with a single detection. Clearly, the maximum values may not be representative of average or likely exposure conditions.

It should also be noted that high background concentrations of boron, chromium, manganese, and nitrate are present throughout the Livermore Valley. Nonetheless, the public health implications of accidental ingestion of all of the preliminary contaminants of concern from storm water runoff and other potential exposure pathways are evaluated in the following section. Ingestion of tritium in surface water was included in cumulative doses estimated by an expert panel convened by ATSDR (ATSDR 2002). Those cumulative, long term tritium doses were also integrated with short term tritium doses from historical tritium releases (ATSDR 2003c). Potential Pu 239 doses from accidental surface water ingestion and contact is evaluated in the following section on Public Health Implications, along with the potential for cumulative exposures to all ionizing radiation.

Table 10. Estimated doses to preliminary contaminants of concern in surface water. Doses are based on potential incidental exposures to maximum measured concentrations.		
Preliminary Contaminant of Concern	**Maximum Concentration in Exposure Area***	**Estimated Dose 0.5 L/week Ingestion Child – Adult**
Boron	6,300 ppb (L-ALPO)	0.045 – 0.006 mg/kg/day
Lead	64 ppb (L-ASW)	0.0005 – 0.0001 mg/kg/day
Manganese	1,300 ppb (L-ASW)	0.009 – 0.001 mg/kg/day
Nitrate	19,000 ppb (L-WPDC)	0.14 – 0.02 mg/kg/day
Pu 239 (incl. Pu 239/240)	0.0018 pCi/L (L-WPDC)	0.00001 – 0.00003 mrem/year
Tritium	35,000pCi/L (L-ALPN)	0.1 mrem/yr (from ATSDR 2002)
*Effluent stations on site or other off site location. These dose calculations assume incidental ingestion of 0.5 L of water per week and child and adult body weights that averaged 10 and 70 kg (respectively; with a lognormal distribution).		

Air

Background, Sources, and Exposures to Airborne Releases

In compliance with local, state, and federal air quality laws, LLNL conducts both effluent source and ambient air monitoring programs. Currently, LLNL operates 77 sampling systems at 7 potential source facilities and monitors 23 ambient air sampling locations on the LLNL property and throughout the Livermore Valley (Gallegos 2002). Current and historic results from the air monitoring programs, which have been transmitted to ATSDR, consist of 2,847 records for non-radiologic substances (primarily beryllium) and 47,515 records for radionuclides (primarily tritium, Pu 238, 239, gross alpha, and gross beta). The electronic data base is supplemented with historic data from annual environmental reports and other documents.

Tritium is the primary radiologic material released into the air by LLNL operations. An expert panel convened by ATSDR reviewed the tritium operations, releases, and monitoring program and concluded that the monitoring program adequately measures potential emissions and is protective of public health (ATSDR 2002).

ATSDR also evaluated the potential short term (acute) doses due to historic accidental tritium air releases. Estimated cumulative annual doses for the years of the accidental releases (1965 and 1970) were most likely less than 41 mrem/year for a child and less than 11 mrem/year for an adult (ATSDR 2003c). Although tritium releases and off site exposures are assumed to represent a completed exposure pathway, the evaluations have shown that the maximum estimated doses are not expected to cause adverse health effects and are therefore below levels of public health concern. The potential contribution of these tritium doses to a cumulative radiologic dose is evaluated in the following section on Public Health Implications.

In addition to tritium, LLNL also uses and potentially releases into the air other radionuclides including, isotopes of uranium, plutonium, cesium, and beryllium. Air monitoring results for these radionuclides have rarely indicated any detections of these nuclides above background values. Re-suspension of Pu 239 (and associated radionuclides) from areas of contaminated soil or sediment represents the only significant non-tritium source of airborne radionuclides. The soil pathway is discussed in a previous section and in a detailed evaluation of Pu 239-contaminated sludge (ATSDR 2003d). Exposure to contaminated soil via airborne re-suspension has been included in the previous PHA dose estimates (ATSDR 2003d) and will be evaluated for a potential contribution to a cumulative radiologic dose in the following section on Public Health Implications.

Non-radiologic emissions from LLNL are regulated under permits from the Bay Area Air Quality Management District. These emissions include, nitrogen oxides, sulfur oxides, particulate matter, carbon monoxide, and lead. The sources of emissions are painting operations, internal combustion engines, solvent operations (metal machining and cleaning), and boilers (oil and natural gas; Gallegos 2002). Emissions from these sources are not significant relative to normal urban and commercial sources. LLNL is also a potential source of airborne beryllium. The maximum measured air concentration at perimeter and Livermore Valley locations is 0.0002 micrograms per cubic meter (µg/m3). This maximum measured air concentration is less than the air CV (Cancer Risk Evaluation Guide; CREG) of 0.0004 µg/m3 and is consistent with re-suspension of beryllium in background soil. Consequently, beryllium is not a contaminant of concern for the air pathway.

From this review of the potential LLNL air emission sources and monitoring data, tritium and Pu 239 are the only contaminants of concern for the air pathway. Airborne tritium and Pu 239 have also been estimated or measured in areas of off site exposure at higher than background concentrations and consequently represent completed exposure pathways. Although individual assessments of the these pathways have determined that the doses are below levels of public health concern, the following section on Public Health Implications will evaluate the distributions of these contaminants of concern to determine the potential for cumulative radiological doses.

Biota (Foodstuffs)

Ingestion of biota, or food items, such as garden produce, milk, beef, and grapes, grown in areas of contaminated air, soil, or water is a pathway by which people may be exposed to site-related contaminants. With respect to the radiologic contaminants present in off site areas (primarily tritium and Pu 239), the prior Public Health Assessments (ATSDR 2003c, 2003d; respectively) have explicitly included dose contributions from potential ingestion of food items. As the biota pathway is already included and specifically identified in those dose assessments, there is no need for separate consideration of the biota pathway for tritium or Pu 239.

With regard to the estimated dose from food ingestion from the accidental tritium releases, ATSDR (2003c) estimated the short term food ingestion dose for a child in the range of 0.4 to 1.5 mrem (average and 95th percentile, respectively) and an adult dose in the range of 0.1 to 0.4 mrem (average and 95th percentile). These food ingestion doses are based on measured tritium concentrations in vegetation following the 1970 release. The vegetation tritium concentrations were assumed to be a normal probability distribution with a 10th percentile value of 5,000 pCi/L and a 90th percentile value of 680,000 pCi/L and an average value of 343,000 pCi/L.

Additional review of the measured tritium concentrations in vegetation (as suggested by LLNL), has indicated that on site vegetation tritium concentrations are higher than the above 90th percentile value of 680,000 pCi/L. In order to ensure the health protective estimation of the dose assessment, the tritium ingestion doses from the accidental releases have been re-calculated using the higher on site value of 1,200,000 pCi/L as a 90th percentile value (average value of 850,000 pCi/L). The revised 12 day tritium ingestion doses to a maximally exposed person are 0.8 to 2.3 mrem for a child (average and 95th percentile) and 0.2 to 0.6 mrem for an adult (average and 95th percentile). Although these revised short term food ingestion doses are used in estimating cumulative doses, they do not appreciably change the previous tritium dose estimates.

With regard to non-radiologic contamination of biota, the off site distribution of site-related contaminants in air, surface water and soil is limited, which indicates little potential for accumulation of site-related contaminants in food items. VOCs, such as TCE and PCE, were historically present in off site ground water. However, these contaminants rapidly volatize in the atmosphere, are broken down by sunlight, and do not bio-accumulate in plants or animals (ATSDR 1997a/b). Consequently, the biota pathway is not a potential source of exposure for these contaminants.

Public Health Implications

This section of the PHA evaluates the public health implications of community exposures to contaminants present in completed or potentially completed pathways. For each preliminary contaminant of concern in a completed or potentially completed pathway, the following section provides a dose based on a health protective evaluation of contaminant concentrations in exposure areas and exposure factors, such as intake rates and duration of exposure. This section further addresses the preliminary contaminants of concern by determining the potential for cumulative doses across pathways and comparing the cumulative doses with health guidance values (HGs).

HGs, such as the ATSDR MRL, are an estimate of daily human exposure, by a specified route and length of time, to a dose of chemical that is likely to be without a measurable risk of adverse, non-cancerous health effects (see Appendices 1 and 4 for more detailed definitions and derivation of HGs and CVs). HGs are derived from peer reviews of contaminant-specific epidemiological and toxicological studies and include appropriate uncertainty or safety factors. Consequently, although doses greater than the HGs cannot be used to predict adverse health effects, adverse health effects are very unlikely for doses less than the HGs.

An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure. The MRL is derived from exposure levels observed to produce adverse effects, with uncertainties (or safety factors) incorporated into the value. Thus, MRLs are intended only to serve as a screening tool to help public health professionals decide which release situations require more extensive evaluation. While estimated exposure dose levels below an MRL are not likely to produce non-cancer adverse effects, exposure estimates above an MRL do not mean that adverse effects will occur. ATSDR then evaluates the potential for adverse health effects in an exposed community by comparing levels known to produce adverse effects to the estimated site-related doses. This margin of exposure (MOE) approach, along with an evaluation of available epidemiologic, toxicologic, and medical data, is used by health assessors as part of the public health assessment to reach qualitative (rather than quantitative) decisions about hazards posed by site-specific conditions of exposure.

ATSDR also uses Environmental Media Evaluation Guides (EMEGs) and Reference Dose Media Evaluation Guides (RMEGs) to evaluate environmental concentrations of contaminants. The derivation of the EMEGs and RMEGs from MRL and other health comparison values is described in Appendix 4. Media concentrations less than the EMEGs or RMEGs are not expected to pose a health threat. RMEGs are media-specific chemical comparison values derived from EPA's RfDs. RfDs are health-based guidelines for non-cancer effects. An RfD is an estimate of the amount of a chemical that a person can be exposed to, on a daily basis that is not anticipated to cause adverse health effects over a person's lifetime. MCLGs, which EPA sets after reviewing health effects studies, are the maximum levels of contaminants in drinking water at which no known or anticipated adverse effect on the health of persons would occur, and that allow an adequate margin of safety. MCLGs are non-enforceable public health goals. When determining an MCLG, EPA considers the risk that sensitive sub-populations (infants, children, the elderly, and those with compromised immune systems) will experience various adverse health effects. For chemicals that can cause adverse non-cancer health effects, MCLGs are based on RfDs.

Specifically, this section will;

1) Summarize the preliminary contaminants of concern in order to derive cumulative exposures across pathways,
2) Summarize the exposure factors that are used to address the specific vulnerability of women and children to contaminants of concern,
3) Compare the resulting cumulative doses with HGs to derive final contaminants of concern,
4) Evaluate the potential for adverse public health effects for the each final contaminant of concern, and
5) Determine the potential for adverse health effects from cumulative doses of ionizing radiation and multiple chemical exposures.

Cumulative Exposures Across Completed and Potentially Completed Pathways

Table 11 summarizes all of the completed or potentially completed pathways of exposure for LLNL-related contaminants as well as those contaminants that may be present at background levels or non-LLNL related sources. Table 11 also identifies the types of exposure, the specific groups of people that may be exposed, and the pathway status with respect to past, present, or future exposure. Of the seven groundwater contaminants, only boron is present above comparison values in multiple pathways (surface water). Of the seven ground water contaminants, only chromium-6, PCE, and TCE appear to be related to LLNL releases. Potential exposures to these site-related contaminants are restricted to a few residences with private wells as listed in Table 3.
Exposure to the non site related contaminants may be occurring throughout the Livermore Valley due to natural distributions of metals (boron, chromium, and manganese) or agricultural and other sources (nitrate).

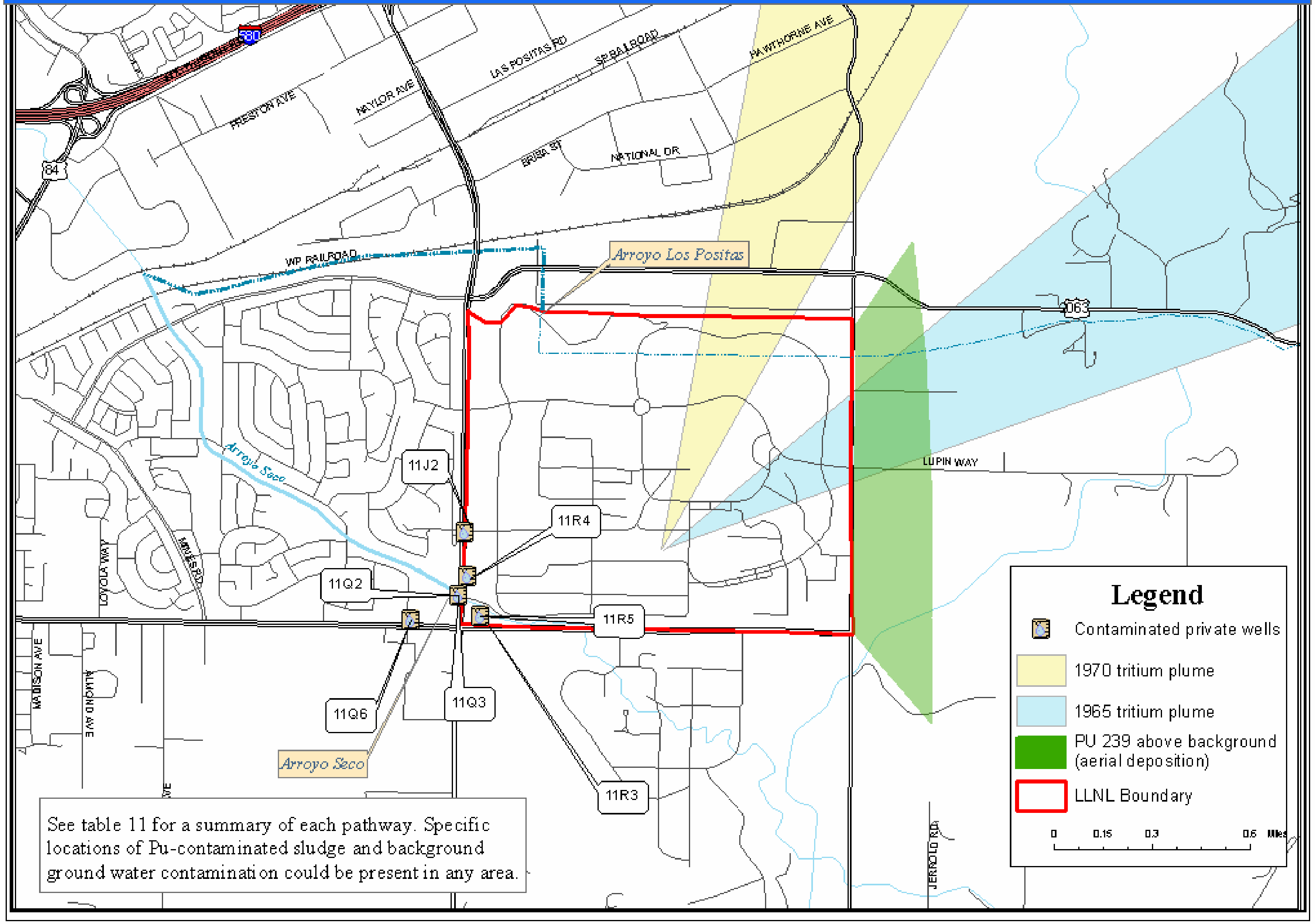
Pu 239 and tritium are the only other preliminary contaminants of concern, and both are present in multiple pathways (Table 11). Previous PHAs dealing with Pu 239 and tritium addressed cumulative exposures across pathways for the individual nuclides (and the radionuclides associated with Pu 239). The geographic areas of potential exposure for all of the preliminary contaminants of concern are illustrated in Figure 3.

Special Consideration of Women and Children

Fetuses of pregnant women and children may be especially vulnerable to exposures from environmental contaminants. These vulnerabilities may be due to increased toxicologic effects on children or developing fetuses in pregnant women or the increased exposure potential of children resulting from a higher ratio of intake rates to body weights. This potential vulnerability is specifically addressed in all of the exposure and dose estimates developed or referenced in this PHA by using intake rates and body weights appropriate to a child (Appendix 4).

For all contaminants and pathways, estimated doses to a child are higher than adult doses and the following evaluation of the "Contaminants of Concern" is driven by these doses to children. The specific factors leading to increased child or fetal doses are explicitly described in the preceding section on "Environmental Contamination and Exposure Assessment" and the PHAs dealing with tritium and Pu 239 exposures (ATSDR 2003c, 2003d; respectively). Also, the MRLs used to evaluate the potential for adverse health effects from exposures to environmental contaminants have been specifically developed to consider the adverse health effects to especially sensitive people such as women and children (Appendix 4). Consequently, the exposure estimates and potential for adverse health effects to fetuses and children are explicitly addressed in this PHA.

Figure 3. Areas of potential off-site exposure to LLNL specific contaminants



See table 11 for a summary of each pathway. Specific locations of Pu-contaminated sludge and background ground water contamination could be present in any area.

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Table 11. Summary of Preliminary Contaminants of Concern for each Pathway including the exposed populations and status of each pathway. The locations of the exposure areas are shown in Figure 3. *Note that Pu 239 exposures include measurements of Pu 239 and Pu 239/240.

Pathway (Media)	**Preliminary Contaminants of Concern**	**Type of Exposure(s)**	**Exposed Population**	**Pathway Status**
Ground water	Boron chromium (total), chromium-6, manganese nitrate PCE TCE	Ingestion, inhalation, and dermal for PCE and TCE; ingestion only for others	Livermore Valley wells for boron, chromium, manganese, and nitrate; residences with wells adjacent to western boundary for chromium-6, PCE, and TCE	Complete past, present, and future for Livermore Valley; Complete only in past for private wells adjacent to LLNL west boundary.
Soil/Sediment	Pu 239*, Tritium	Ingestion and inhalation, also dermal absorption for tritium	People living downwind of the 1965/70 tritium releases or on sludge-contaminated properties.	Complete past, present, and future
Surface water	Boron Pu 239*, Tritium	Ingestion, also inhalation and dermal absorption for tritium	Children playing in the Arroyos, drainage maintenance workers	Potentially complete for past, present, and future
Air	Pu 239*, Tritium	Inhalation, dermal absorption, and ingestion	People living downwind of the 1965 or 1970 tritium releases or on sludge-contaminated properties.	Complete past, present, and future
Biota (food items)	Pu 239*, Tritium	Ingestion	People with home gardens that used contaminated sludge or were downwind of tritium releases	Complete past, present, and future

Contaminants of Concern

Table 12 lists the pathway-specific and cumulative doses and HGs for each preliminary contaminant of concern. Of the seven contaminants, only the doses for boron, nitrate, and PCE exceeded the respective HG value and are identified as final contaminants of concern. The health implications of exposure to boron, nitrate, and PCE are addressed in this section. Exposures to chromium, chromium-6, manganese, TCE, Pu 239, and tritium are below health guidelines and are unlikely to produce any adverse health effects. The pathway-specific and cumulative doses for Pu 239 and tritium are from previous PHAs (ATSDR 2003d, 2003c; respectively).

The non-radiologic doses listed in Table 12 are estimated from 95th percentile concentrations for ground water and maximum concentrations for surface water. The Pu 239 and tritium doses are average doses for maximally exposed individuals. Because of the lognormal distribution of the estimated doses, the most likely doses to the maximally-exposed individuals are less than the average doses. Also, because of the health protective exposure assumptions used in estimating all of these doses, it is unlikely, albeit possible, that doses to members of the Livermore community exceeded the average values (ATSDR 2003c/d). Although Pu 239 and tritium are not identified as final contaminants of concern, detailed discussions of the toxicology and potential health effects of those substances are presented in previous PHAs (ATSDR 2003d and 2003c; respectively).

Doses for boron, nitrate, and PCE are estimated with a Monte Carlo simulation using the Crystal Ball Forecasting and Risk Analysis software (Version 4.0, Decisioneering Inc. 1996). The dose equation and exposure factors are listed in Table 4. Body weights and contaminant concentrations are the only probabilistic variables in these calculations.

Table 12. Pathway specific and cumulative doses for the preliminary contaminants of concern. Cumulative doses for boron, nitrate, and PCE exceed health guidelines and these contaminants are selected as final contaminants of concern with further evaluation of potential health implications.

Preliminary Contaminant of Concern	**Pathway dose mg/kg/day Child – Adult**	**Total dose mg/kg/day Child -- Adult**	**Health Guideline mg/kg/day**	**Do Doses exceed Health Guidelines?**
Boron	GW 0.15 – 0.08 SW 0.045 – 0.006	0.20 – 0.09	0.09 RfD-oral	**YES**
Chromium	GW 0.005 – 0.002	0.01 – 0.003	1.5 (Cr-3) RfD-oral	No
Chromium-6	GW 0.002 – 0.001	0.002 – 0.001	0.003 RfD-oral	No
Manganese	GW 0.13 – 0.07 SW 0.009 – 0.001	0.14 – 0.071	0.14	No
Nitrate	GW 4.3 – 2.3	4.4 – 2.3	1.6	**YES**

Table 12. Pathway specific and cumulative doses for the preliminary contaminants of concern. Cumulative doses for boron, nitrate, and PCE exceed health guidelines and these contaminants are selected as final contaminants of concern with further evaluation of potential health implications.

Preliminary Contaminant of Concern	**Pathway dose mg/kg/day Child – Adult**	**Total dose mg/kg/day Child -- Adult**	**Health Guideline mg/kg/day**	**Do Doses exceed Health Guidelines?**
	SW 0.14 – 0.02		RfD-oral	
PCE	GW 0.05 – 0.03	0.05 – 0.03	0.01 RfD-oral	**YES**
TCE	GW 0.004 – 0.002	0.004 – 0.002	0.2 MRL a-oral	No
Preliminary Contaminant of Concern	**Pathway dose mrem/yr Child or Adult**	**Total Dose+ mrem/yr Child or Adult**	**Health Guideline mrem/yr**	**Do Doses exceed Health Guidelines?**
Pu 239 Pu 239/240	Soil Air Biota 0.31 (ATSDR 2003d) SW 0.00003	0.31	100 mrem/yr** MRL	No
Tritium	Soil Air Biota SW	41 – 11* (ATSDR 2003c)	100 mrem/yr** MRL	No

GW-- ground water
SW-- surface water
RfD-- reference dose (EPA comparison value; Appendix 4)
MRL-- minimal risk level (ATSDR comparison value; Appendix 4).
+ Summation of total doses as committed effective dose equivalents and annual doses, while technically inaccurate, is common practice per RESRAD documentation (ANL 2001) for comparison with annual dose limits.
*Tritium doses are average total annual doses to maximally exposed individuals for years of large accidental releases.
**Although MRLs typically include only non-cancer health effects, all of the studies underlying the MRL for chronic exposure to ionizing radiation (100 mrem/year) included cancer as a health effect so that the MRL for ionizing radiation is protective for both cancer and non-cancer health effects (ATSDR 1999c). The acute MRL (400 mrem) is based on adverse developmental effects.

Boron

Boron is a solid substance that widely occurs in nature (this summary is derived from the ATSDR Toxicological Profile on Boron; ATSDR 1992b). It usually does not occur alone, but is often found in the environment combined with other atoms to form compounds called borates. Common borate compounds include boric acid, salts of borates, and boron oxide. Boron and salts of borate have been found at hazardous waste sites. Boron compounds occur mainly in the environment through release into air, water, or soil after natural weathering processes. They can also be released from glass manufacturing, coal-burning power plants, copper smelters, and through its use in agricultural fertilizer and pesticides. It is estimated that releases from these sources are less than through natural weathering processes.

Exposure to boron (as borate compounds) may also occur from the use of consumer products, including cosmetics, topical medical preparations, and some laundry products. The average daily boron intake has been estimated to be 10–25 mg (0.14 to 0.35 mg/kg/day for a 72 kg adult). Most of the boron leaves the body in urine primarily from food eaten. Over half of the boron taken by mouth can be found in urine within 24 hours and the other half can be detected for up to 4 days. Boron compounds can be found in urine up to 23 days if you are accidentally exposed to very large amounts.

Irritation of the nose and throat or eyes has occurred in long-term borax workers (mean inhalation exposures to 4.1 mg/m^3 in air; ATSDR 1992b). Boron compounds (as borates or boric acids) can irritate the eyes if it comes in contact with them for long periods of time. Irritation of the nose can occur in animals if large amounts (air concentrations of 470 mg/m^3; ATSDR 1992b) of boron are breathed in for long periods of time. These effects have not been seen in humans. If humans eat large amounts of boron (more than 90 mg/kg/day for an infant) over short periods of time, it can affect the stomach, intestines, liver, kidney, and brain and can eventually lead to death. Animal studies indicate that the male reproductive organs, especially the testes, are affected if large amounts (doses greater than 40 mg/kg/day; ATSDR 1992b) of boron compounds are eaten or drunk for short or long periods of time. Studies in animals also indicate delayed development and structural defects in offspring, primarily in the rib cage, from maternal exposure to boron during pregnancy. These effects have not been seen in humans. No information is available on whether boron compounds are likely to cause cancer in humans. There is no evidence of cancer in animals exposed to boron compounds for long periods of time.

Estimated boron doses from chronic ingestion of Livermore Valley ground water and incidental ingestion of storm water runoff from the LLNL facility are presented in Figure 4. These doses are based on body weights and intake rates of a child and the 95^{th} percentile of boron ground water concentrations and maximum storm water concentrations. The average dose is about 0.06 mg/kg/day and the 95^{th} percentile dose is 0.22 mg/kg/day. While the 95^{th} percentile dose exceeds the reference dose of 0.09 mg/kg/day (Table 12), it is much lower than any doses related to adverse health effects in animals or humans (ATSDR 1992b).

In laboratory studies, chronic boron doses (soluble boric acid) of 4.4 to 17.5 mg/kg/day to dogs and rats did not produce any observable adverse health effects (NOAEL; ATSDR 1992b). Doses of 26 to 44 mg/kg/day did produce reversible adverse health effects (partial testicular atrophy). Culver et al. (1994) measured "daily dietary-boron intake and on-the-job inspired boron blood- and urine-boron concentrations in workers engaged in packaging and shipping borax…. Total estimated boron intake, which is diet plus environmental exposure, had for the high-borax dust exposure group a mean daily boron intake of 27.90 mg/day or, based on the body weights of the subjects, 0.38 mg boron/kg/day. These subjects had a mean blood-boron level of 0.26 µg boron/g blood, a factor of 10 lower than found in the dog or rat at NOAEL exposure levels."

As the conservatively estimated boron doses from drinking water in the Livermore area are more than 100 times lower than any doses associated with observed adverse health effects and are within the range of normal background intake rates, chronic ingestion of Livermore Valley ground water and incidental ingestion of storm water runoff from LLNL is not a public health hazard.

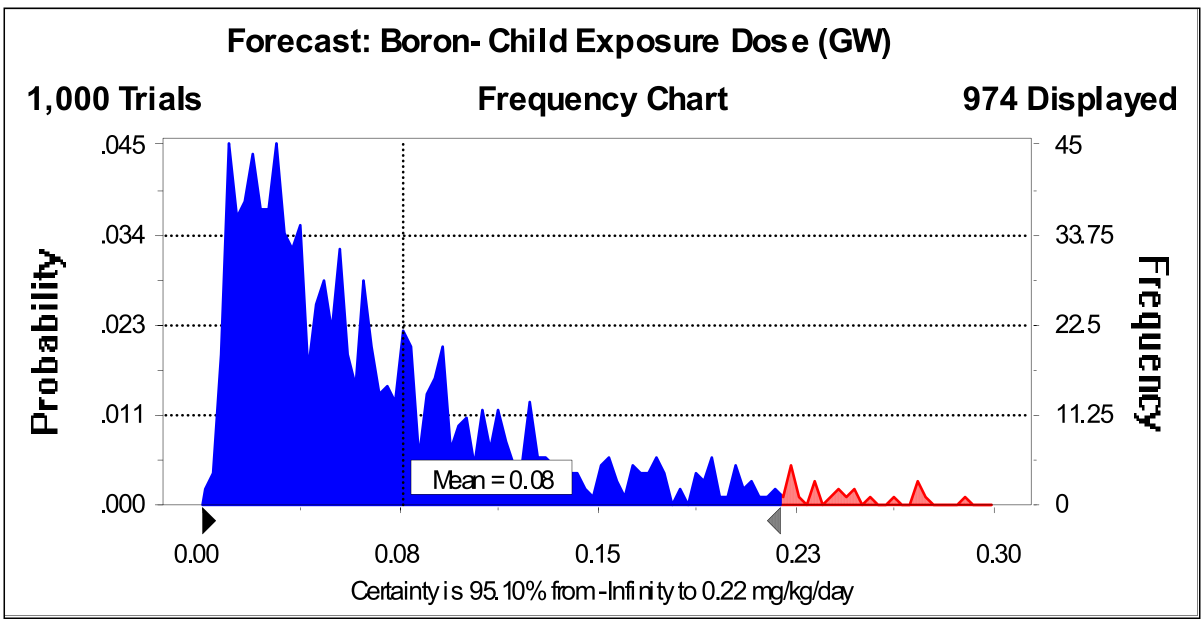

Figure 4. Estimated boron doses to a child from exposure to ground water and surface water adjacent to the LLNL facility. Boron concentrations in ground water are naturally-occurring throughout the Livermore Valley. The surface water dose contribution is based on maximum concentrations in storm water runoff from the LLNL facility. Doses are in units of mg [boron] per kg [body weight] per day.

Nitrate

The following summary of nitrate toxicity is derived from the ATSDR Case Study in Environmental Medicine Nitrate/Nitrite Toxicity (ATSDR 2001). Nitrate and nitrite are naturally occurring compounds, part of the nitrogen cycle. Because nitrite is easily oxidized into nitrate, nitrate is the form that is typically found in groundwater and surface water. Nitrate is the primary source of nitrogen for plants. Wastes containing organic nitrogen are decomposed in soil or water by bacteria to form ammonia. Ammonia is then oxidized to nitrite and nitrate. Agricultural and residential use of nitrogen-based fertilizers, nitrogenous wastes from livestock and poultry production, and urban sewage treatment systems have increased levels of nitrate in soil and water. Certain plants (cauliflower, spinach, collard greens, broccoli, carrots, and other root vegetables) have naturally higher nitrate contents than other plant foods and can account for a large percentage of nitrate in the diet. Nitrate and nitrite compounds are also used for color enhancement and preservation of processed meat products. Nitrate is used in foods to prevent botulism, a life-threatening food-borne illness.

Nitrate-containing compounds are water soluble, which means that they can be carried in water. Thus, nitrate can enter drinking water supplies through surface water runoff, home sewage systems, agricultural fields, and groundwater recharge. In agricultural areas, a seasonal pattern of increased nitrate levels in drinking water has been seen. This increase occurs most often in spring, when fertilizers are applied and nitrate is transported through storm runoff or groundwater recharge. The most common route of exposure occurs through drinking contaminated water, eating vegetables with naturally high levels of nitrate, and eating foods preserved with nitrate.

Nitrate can affect the blood's ability to carry oxygen. Nitrate's acute toxicity is due to its biological conversion to nitrite, which oxidizes ferrous iron in the hemoglobin producing methemoglobin. Methemoglobin interferes with the oxygen transport system in the blood. Methemoglobinemia (blue-baby syndrome) is caused by high levels of nitrite (or indirectly, nitrate) in the blood. Infants are more sensitive to nitrate for several reasons. They consume more water relative to their body weight than adults, and the hemoglobin in an infant's blood (called fetal hemoglobin) is more easily changed into methemoglobin than an adult's hemoglobin. Also, an infant's digestive system is less acidic, which enhances the conversion of nitrate to nitrite. The two most common symptoms related to the consumption of water with high levels of nitrate are methemoglobinemia and acute diarrhea. Fatalities from methemoglobinemia occur infrequently and are most common in rural areas. Illness and death caused by methemoglobinemia are not always recognized, so methemoglobinemia occurrence may be under-reported.

Families with infants should use an alternate water supply if their well is known to contain elevated levels of nitrate. When preparing infant formula, families should use nitrate-free water. If a private well is used, it should be inspected for proper construction and tested for nitrate and bacteria levels. Ingestion of foods containing nitrate or nitrite have caused symptomatic methemoglobinemia in children.

Nitrates can react with other substances to form N-nitroso compounds. Some of these N-nitroso compounds have caused cancer in animals. However, the mechanism for this is not well defined. Human and experimental animal studies have failed to provide conclusive evidence that ingestion of nitrate or nitrite causes cancer (Weyer 2004). However, recent studies have shown an increased stomach and esophygeal cancer risk due to ingestion of nitrate (CancerWeb 2004). The EPA does not currently provide an assessment of the cancer potential of nitrate (EPA 2004).

In order to determine whether the potential exposures to nitrates presents a public health hazard, ATSDR compared the estimated doses with benchmarks or screening doses that are derived from dose levels known to produce adverse health effects. The chronic RMEGs for a child are 20 mg/L for nitrate-nitrogen (NO_3-N) and 90 mg/L for NO_3; for adults, the chronic RMEGs are 60 mg/L for NO_3-N and 270 mg/L for NO_3. The RMEG for nitrate is not protective of infants, so ATSDR recommends using EPA's Maximum Contaminant Level Goal, or MCLG (10 mg/L for NO_3-N) as a guideline to evaluate potential infant exposure. EPA requires that the amount of nitrate (as NO_3-N) in public drinking water supplies not exceed 10 mg/L. (This regulation does not cover private wells.) If the results of a water analysis are reported as NO_3 (total nitrate) instead of NO_3-N, the equivalent value would be 45 mg/L. The RfD for nitrate is 1.6 mg/kg/day (EPA 2004).

Figure 5 illustrates the distribution of estimated nitrate doses to a child from ingestion of ground water from water wells throughout the southeastern Livermore Valley. The 95th percentile dose is about 4.5 mg/kg/day, the average dose about 1.6 mg/kg/day, and the most likely dose about 0.5 mg/kg/day. Both the average and most likely estimated doses are below the health guideline of 1.6 mg/kg/day. Numerous monitor wells throughout the area have elevated nitrate concentrations, however, only one inactive private well (14B1) had elevated nitrate concentrations. The high nitrate concentrations are not distributed as a plume emanating from the LLNL facility and may be associated with widespread agricultural activities.

Based on the information presented above, the average or most likely nitrate doses are not expected to cause an adverse public health effect in adults, infants, or children. The 95th percentile dose for a child is about 3 times greater than the applicable health guideline (1.6 mg/kg/day, RfD; Table 12). This dose is based on the 95th % nitrate concentration of 80,120 ppb (Table 4). Although no off site drinking water wells showed this level of contamination, because of the apparently random distribution of elevated nitrate concentrations in the shallow aquifers, nitrate concentrations capable of producing adverse health effects are possible throughout the Livermore Valley. The LLNL-specific ground water monitoring data evaluated in this assessment is not intended nor capable of resolving potential area-wide agricultural contamination. Further evaluation of this issue is recommended.

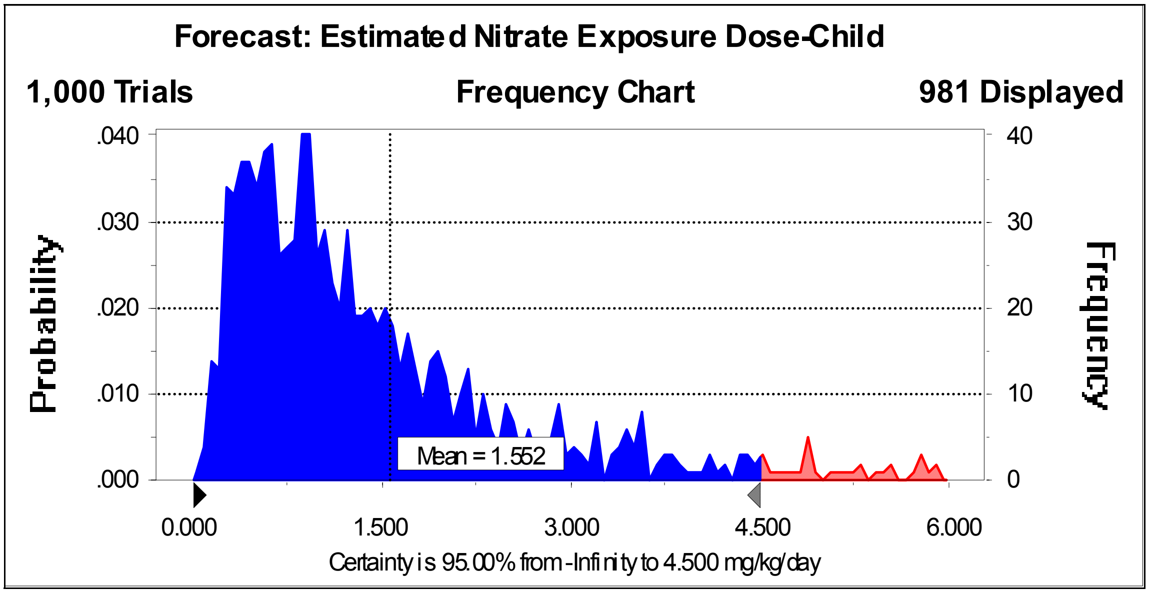

Figure 5. Distribution of potential estimated nitrate dose to a child from ingesting ground water from private wells throughout the southeastern portion of Livermore Valley. Note that the 95th percentile dose is about 4.5 mg/kg/day, while the average dose is about 1.6 mg/kg/day and the most likely dose is about 0.5 mg/kg/day. The distribution of elevated nitrate concentrations in ground water wells appears to be randomly distributed throughout the Valley and not likely related to LLNL releases or emissions. Doses are in units of mg [nitrate]per kg [body weight] per day.

Ionizing Radiation (Tritium and Pu 239)

High doses of ionizing radiation (acute exposures well in excess of 5,000 mrem) can cause significant adverse health effects, such as skin burn, hair loss, birth defects, cancers, and death (ATSDR 1999c). However, as with exposures to all hazardous substances, it is the dose which determines whether such health effects are likely to occur. In order to determine whether the potential exposures to radioactive substances presents a public health hazard, ATSDR compared the estimated doses with benchmarks or screening doses that are derived from dose levels known to produce adverse health effects. For ionizing radiation, which includes tritium and plutonium (and its decay products), ATSDR has developed minimal risk levels (MRLs) that cover brief exposures (acute, or less than 14 days) and longer term exposures (chronic, or more than a year).

On the basis of an extensive review of the health studies and documented health effects from radiological exposures, ATSDR established an MRL of 400 mrem for acute duration (14 days or less) of external exposure* (ATSDR 1999) to ionizing radiation. The acute MRL is based on external dose levels that did not produce behavioral and/or neurological effects on the developing human embryo and fetus. Similarly, a chronic duration (a year or more) -external exposure MRL of 100 mrem/year (above background) has been established based on radiation doses that have not produced observable detrimental health effects in humans. Thus, the ATSDR acute and chronic MRLs for ionizing radiation are based on doses with "no observed adverse effect levels" (NOAELs). While ATSDR MRLs typically include only non-cancer health effects, all the studies on which the chronic MRL for ionizing radiation are based included cancer as the specific end-point. Consequently, the chronic MRL for ionizing radiation is considered protective for both cancer and non-cancer health effects.

Adverse health effects have been conclusively demonstrated for exposures greater than 10,000 mrem/year (ATSDR 1999c). Numerous studies have also demonstrated that no adverse health effects have been documented for doses less than 360 mrem/year which is the average national background exposure to ionizing radiation (ATSDR 1999c)†. The uncertainty in the dose effects lies within the middle ranges of exposure. The ATSDR minimal risk level (MRL) for ionizing radiation is based on numerous evaluations of health effects from exposures to background and occupational levels of radiation. "The annual dose of 3.6 mSv per year (360 mrem/year) has not been associated with adverse health effects or increases in the incidence of cancers in humans or animals." (ATSDR 1999c). Consequently, 360 mrem/year (above background) is defined as a NOAEL. The derived MRL, which is further reduced by a factor of 3 to account for human variability (and conservatively rounded down from 120 mrem/year to 100 mrem/year; above background), is protective of human health.

ATSDR also evaluates the potential for cancer risk by first comparing the estimated dose levels to a theoretical risk level, usually the dose level associated with a 10^{-6} risk (one in a million) as defined by other governmental agencies. ATSDR designates these screening levels as Cancer Risk Evaluation Guides (CREGs). As with the non-cancer approach, levels less than 10^{-6} require no further evaluation, while estimated dose levels that exceed the 10^{-6} value are evaluated further. The potential for observing adverse effects is made on the basis of dose evaluation (an MOE approach), rather than on the basis of theoretical risk calculations. (See below discussion on

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* Although the ATSDR MRLs for ionizing radiation are specific to external exposure, the value of 100 mrem/year is consistent with those for either external or internal exposures promulgated by the US Nuclear Regulatory Commission, the National Commission on Radiation Protection, and the International Commission on Radiation Protection (as referenced in ATSDR 1999c).

† In the United States, background consists of naturally-occurring radon (54%), terrestrial and cosmic radiation (8% each), and internal (11%). The remainder (19%) is associated with medical exposures and consumer products. The typical average background radiation in the United States is 360 mrem/year. Average external terrestrial (natural radionuclides in soil) radiation exposures for the San Francisco area are about 44 mrem/year with a 95^{th} percentile value of about 80 mrem/year (NCRP 1987).

dose-based approaches for health assessment versus risk-based approaches used by regulatory agencies).

In contrast to the dose-based health assessments conducted by ATSDR, the United States Environmental Protection Agency (EPA) develops regulations based on risk and policy decisions. To accommodate proper evaluation of the dose and risk issues associated with radiation exposure, it is necessary to clearly define the terms *dose* and *risk*. The International Society for Risk Analysis (www.sra.org) defines **risk** as "*The potential for realization of unwanted, adverse consequences to human life, health, property, or the environment; estimation of risk is usually based on the expected value of the conditional probability of the event occurring times the consequence of the event given that it has occurred*." As defined, risk is a statistical concept, and the threshold for acceptable risk, which is not based on observable adverse health effects, is simply a policy statement. Risk Assessments are useful in determining safe regulatory limits. The regulatory limits have extra safety factors built into them and may in fact be orders of magnitude below levels at which adverse effects have been documented to occur in humans. Risk assessments are useful for purposes of prioritizing cleanup activities.

ATSDR defines **dose** as *"The amount of a substance to which a person may be exposed, usually on a daily basis. Dose is often explained as "amount of substance(s) per body weight per day"*. Doses are the basis for determining levels of exposure that may cause adverse health effects and may be directly related to the assessment of public health. As noted above, ATSDR uses risk assessment procedures as a screening tool in its evaluation, including MOE approaches along with the consideration of health effects data (epidemiologic, toxicologic, and medical) to reach conclusions about the potential for adverse effects being observed in the community.

More specifically, ATSDR uses radiation doses ***instead of risk*** in its public health documents for various reasons. Among these are the facts that dose coefficients are based on a more exact science; that is, the doses are based on physical constants and primary principles of physics such as energy absorption. Health effects resulting from radiation doses are based on a "weight-of-evidence" approach. ATSDR, in preparing its public health documents, also relies on site-specific parameters such as demographics, land use, and other pertinent data related to the site. Using dose coefficients and modifying the coefficients for chemical forms and particle sizes, which are not typically done for risk assessments, allows ATSDR to develop health-protective, albeit realistic, values for the dose assessments as they pertain to public health documents.

Similarly, radiation health studies use ***dose*** because there is a long history of research in which health outcomes were evaluated relative to the radiation dose and not on the numerical estimation of risk. ATSDR also recognizes there are uncertainties in these dose coefficients; however, those uncertainties are addressed by the use of health protective safety factors. Risk calculations include those uncertainties plus additional uncertainty associated with the risk estimation model. Consequently, the derivation of quantitative risk is much more uncertain than the underlying dose-based assessment.

The science associated with risk is based on a model that, at low doses typically associated with small multiples of background, cannot be proven. ATSDR also realizes that every action, radiation dose, or activity has an associated risk. However, because no adverse health effects have been observed at doses considerably higher than 100 mrem/year (above background), there is no public health basis for using highly uncertain, risk-based screening values. Acute exposures to plutonium and tritium via the inhalation, ingestion, and dermal pathways, as described in this health assessment, resulted in cumulative doses of less than 400 mrem or in chronic exposures less than 100 mrem/year (above background and averaged over 5 years). These doses are unlikely to produce any adverse health effects and therefore are below levels of public health hazard.

Tetrachloroethylene (PCE)

Tetrachloroethylene (also known as perchloroethylene or PCE) is a chlorinated hydrocarbon used primarily as a dry-cleaning solvent, a vapor-degreasing solvent, and a drying agent for metals; it is also used in the manufacture of fluorocarbons (Hawley 1987). Not known to occur naturally, PCE enters the environment from sources such as vaporization losses from dry cleaning and metal degreasing industries, and leachate from vinyl liners in asbestos-cement water pipelines used for water distribution (HSDB 1992). The general population will be exposed to PCE through inhalation of contaminated ambient air and ingestion of contaminated drinking water, especially from polluted groundwater sources (ATSDR 1997a). Most absorbed PCE is eliminated unchanged via the lung (Ellenhorn and Barceloux 1988). PCE's long half-life (65 hours) in human breath is probably due to deposition in fat and other tissues. Only limited metabolism of PCE takes place in humans. The metabolism of PCE is apparently saturated at concentrations well below 100 parts per million (ppm) in air (ATSDR 1997a).

PCE is only slightly, to moderately toxic in laboratory animals. In mice and rats, the oral LD_{50} (the orally-administered dose that will kill half of all treated animals) is 8,850 and 2,600 mg/kg, respectively (Patty 1981). The liver is the primary target in animals (Andrews and Snyder 1991) but is seldom the target in humans. Ingestion of a small amount of undiluted PCE is unlikely to cause permanent injury. In fact, PCE was formerly used as a remedy for intestinal worms; oral doses of 2.8 – 4.0 ml (4,500 – 6,500 mg) given for this purpose were quite effective (HSDB 1992; ATSDR 1997a). Inebriation was the only troublesome side effect noted in 46,000 patients. In one case, however, a 6 year old boy was admitted to the clinic in a coma after ingesting 12 to 16 grams (HSDB 1992; ATSDR 1997a). The clinical condition of the patient improved considerably with hyperventilation therapy. A reversible jaundice and hepatomegaly were also observed in a 6 week old infant breast-fed on milk containing PCE (HSDB 1992).

The following known health effects of PCE have usually been the result of occupational exposure to high concentrations, primarily by inhalation. The odor threshold is around 50 ppm (HSDB 1992). In excess of 100 ppm, PCE is irritating to mucous membranes and the respiratory tract (Ellenhorn and Barceloux 1988) and may produce largely reversible effects in the liver (HSDB

1992). The major response to high concentrations (in the order of 200 to 500 ppm) of PCE is depression of the central nervous system (CNS), for example, dizziness, headache, vertigo, inebriation and unconsciousness (10). There was no response in men or women repeatedly exposed to 100 ppm for 7 hours *per* day (AGCIH 1986). In another study, electroencephalograph scores suggested cerebral cortical depression in 4 male subjects exposed by inhalation to 100 ppm PCE for 7.5 hours/day for 5 days (Hake and Stewart 1977). However, no neurological effects were identified by a battery of behavioral and neurological tests. Exposures to high concentrations (> 200 ppm, causing unconsciousness, have resulted in proteinuria, hematuria, and pulmonary edema (HSDB 1992). In the event of prolonged dermal contact with the undiluted solvent, the defatting properties of PCE can result in erythema, vesiculation, and fissure formation, which predisposes the skin to infection.

PCE is a non-genotoxic animal carcinogen. In chronic bioassays (1.5–2.0 yrs), massive doses of PCE administered orally (up to 1,072 mg/kg/day) or by inhalation (100–200 ppm), have produced liver cancer in mice, but not in rats; administered by inhalation (200–400 ppm), it has also caused a statistically <u>in</u>significant increase in kidney tumors in male, but not female rats (ATSDR 1993). However, recent re-evaluations of these studies by various government agencies and independent scientists indicate that the tumors observed in animals were probably due to species-specific mechanisms that exhibit thresholds at near-toxic levels (reviewed in ATSDR 1997a). That is to say that the induction of cancers in mice and rats by PCE required doses in excess of anything humans might reasonably be expected to encounter, and involved certain elements of rodent biology that are not likely to be shared by humans (peroxysome proliferation, α-2μ-globulin accumulation). The implication is that the cancers observed in laboratory animals at very high doses of PCE have little or no relevance for human risk evaluation at environmental levels of exposure that are orders of magnitude lower. In fact, a number of epidemiological studies of men and women exposed occupationally to PCE have not identified an increased risk of cancer (ATSDR 1997a).

The International Agency for Research in Cancer (IARC) classifies PCE as "possibly carcinogenic to humans" based on "sufficient" evidence of carcinogenicity in animals and "inadequate" evidence of carcinogenicity in humans, and the National Toxicology Program (NTP) classifies PCE as *reasonably anticipated to be a carcinogen* (RAC) in humans (ATSDR 1993). However, both IARC and NTP use a "<u>strength</u> of evidence" basis of classification which does not allow consideration of mechanisms of action. The EPA, by contrast, uses a "<u>weight</u> of evidence" basis of classification, which allows that agency the option of taking mechanistic data into account. EPA's carcinogen classification scheme was developed at a time when little or no data on mechanism of action were available for consideration, with the result that the carcinogen category that would best accommodate such data does not exist. This is the case with PCE.

EPA currently has no cancer classification for PCE, although it is under review (EPA 2004). However, there is no question that PCE at high enough doses, administered by the right route to the right species and sex can cause an elevated incidence of certain cancers by species-specific mechanisms in laboratory animals. Thus, EPA previously classified PCE as a B2--C carcinogen not because it could not decide whether the evidence for carcinogenicity in animals was "sufficient" or "limited," but rather because its classification scheme does not include a more appropriate category for this type of carcinogen. The American Conference of Governmental Industrial Hygienists (ACGIH), which does have such a category, classifies PCE as an A3 animal carcinogen, signifying that "the agent is carcinogenic in animals at a relatively high dose, by route(s) of administration, at site(s), of histological type(s), or by mechanism(s) that are not considered relevant to worker exposure" (ACGIH 2003).

In summary, PCE may be a human carcinogen. However, carcinogenic effects occur at much higher doses than non-cancer health effects. Consequently, doses that are protective for non-cancer health effects will also be protective for possible induction of cancer.

Figure 6 illustrates the estimated distribution of PCE doses to an adult exposed to contaminated ground water from a well adjacent to the LLNL facility. Adult doses are about one half of the child doses based on differences in the ratio of ingestion rates and body weights. From this figure, it is apparent that the 95th percentile dose used for comparison with the RfD value (0.01 mg/kg/day) greatly overestimates the most likely doses. The mean or average dose is 0.01 mg/kg/day. Also, the PCE ground water concentrations used in estimating these doses are based on multiple measurements at one off site well with the maximum PCE concentrations (well 11R5). Only adults lived at this location, so long term child doses would not have occurred. The other four residential wells with detectable PCE concentrations had much lower concentrations and were destroyed in the 1980s (Appendix 5).

In summary, PCE is slightly to, moderately toxic in laboratory animals (the doses that have not caused any adverse health effects are in the tens to hundreds of mg/kg/day). In humans, ingestion of small amounts of PCE as shown in Figure 6 is not expected to cause any injury. Human exposure to high levels of PCE, hundreds of times larger than the doses estimated here, may cause acute effects. Although PCE has been categorized in the past as a possible/probable human carcinogen, that conclusion is now being re-evaluated because the induction of cancers in rodents required extremely high doses and involved elements of rodent biology not shared by humans. The health protective doses estimated for past exposures to residents living adjacent to the LLNL are not expected to cause any adverse health effects.

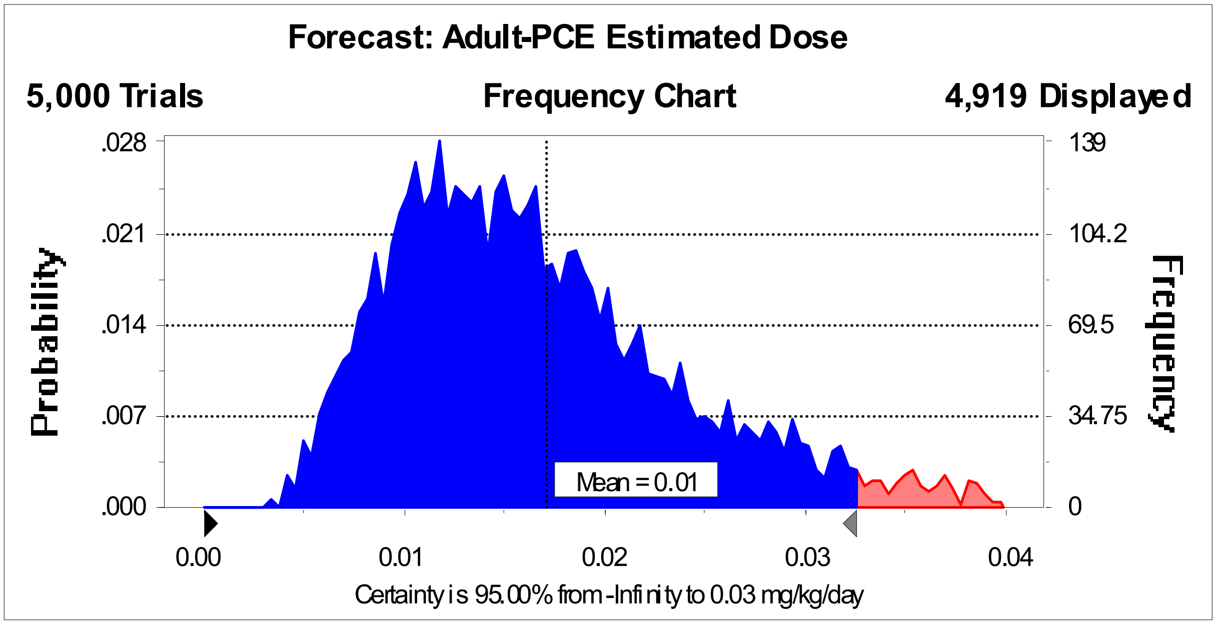

Figure 6. Estimated PCE dose for an adult from a contaminated well adjacent to LLNL. Doses include estimation of ingestion, inhalation, and dermal absorption components. No children lived at the residence served by this well. Note that the average doses are about 0.01 mg/kg/day. These doses are based on measured concentrations from the off site residential well with the highest PCE measurements. Only five residential wells that were destroyed in the 1980s contained detectable concentrations of PCE. Doses are in units of mg [PCE]per kg [body weight] per day.

Potential for Adverse Health Effects from Interactive Effects of Multiple Chemical or Radiological Exposures

ATSDR considered interactive effects (cumulative, additive, synergistic, and antagonistic) of chemicals following exposure to multiple chemicals to the extent of the scientific knowledge in this area.

- *Cumulative effects* (the effects associated with concurrent exposure by all relevant pathways and routes of exposure to a group of chemicals that share a common mechanism of toxicity) were addressed on pages 93 and 94 and in Table 22 of the PHA (ATSDR, 2002).

- *Additive effects* (the situation in which the combined effect of two chemicals is equal to the sum of the effect of each agent given alone) were considered for radioactive materials in the PHA (ATSDR, 2001; pages 119-120). Of the contaminants evaluated in this PHA only ionizing radiation is considered to have additive effects.

- Existing information is inconclusive with regard to potential *synergistic effects* (the situation in which the combined effect of two chemicals is much greater than the sum of the effect of each agent given alone) for the contaminants evaluated in this PHA.

- *Antagonistic effects* (when a chemical reduces the toxicity or uptake of another chemical) were not considered in order to maintain a health-protective screening scenario.

ATSDR has reviewed the scientific literature surrounding chemical interactions and noted that if the estimated exposure doses for individual contaminants detected at the site are below doses shown to cause adverse effects (No Observed Adverse Effect Level; NOAEL), then ATSDR considers that the combined effect of multiple chemicals is not expected to result in adverse health effects. It should be noted that typical environmental exposure doses to both carcinogenic and non-carcinogenic chemicals are more than 100 times lower than laboratory-induced effect threshold doses. This approach to chemical interactions is based on the results of numerous studies:

- Several animal and human studies (Berman et al. 1992; Caprino et al. 1983; Drott et al. 1993; Harris et al. 1984) have reported thresholds for interactions. Studies have shown that exposure to a mixture of chemicals is unlikely to produce adverse health effects as long as components of that mixture are detected at levels below the NOAEL for individual compounds (Hooth et al. 2002; Wade et al. 2002; Seed et al. 1995; Feron et al. 1995).

- The absence of interactions at doses 10-fold or more below effect thresholds have been demonstrated by Jonker et al. (1990) and Groten et al. (1991). Specifically, in two separate sub-acute toxicity studies in rats (Groten et al. 1997; Jonker et al. 1993), adverse effects disappeared altogether as the dose was decreased to below the threshold level.

For carcinogens, the interactions are more difficult to quantify due to the large study size (humans or animals) needed for statistical significance at the low doses observed in environmental exposures. In an animal study, Takayama et al. (1989) reported that 40 substances tested in combination at 1/50 of their cancer effect level (CEL) resulted in an increase in cancer. Hasegawa et al. (1994) also reported no increase in cancer when dosing animals at 1/100 of the CEL for 10 compounds.

The potential health effects from the radioactive contaminants for each exposure pathway were reviewed. Also, the potential health effects from estimated radiation doses from all pathways and types of exposure were considered, as were organ doses. The estimated radiation doses from all media for any year did not exceed 100 mrem (Table 12) for both short-term and long-term exposures and are consequently, below levels of public health concern.

The largest estimated doses are attributed to short term exposures to the accidental tritium releases in 1965 and 1970. These exposures affected a very limited population (fewer than 18 and 52 people, respectively) residing east and northeast of the LLNL facility. It is possible that people living in the discrete areas of the tritium plumes (Figure 3) also obtained Pu-contaminated sludge. Using the health protective assumption that the Pu 239 concentration over an entire residential property has a Pu 239 concentration of 2.5 pCi/g, the resulting dose is about 0.3 mrem/year (Table 12). Summing the potential Pu 239 and tritium doses (41 mrem/year-- child) results in a cumulative dose of less than 42 mrem/year.*

There has been some concern that some unknown areas of sludge contamination may exceed a concentration of 2.5 pCi/g (Pu 239). Although an extensive evaluation has indicated this is unlikely (ATSDR 2003d), if the average Pu 239 soil concentration was 250 pCi/g (100 times greater than the health protective estimate of 2.5 pCi/g), the hypothetical cumulative radiation dose would still be less than the 100 mrem/year MRL (41 mrem/year [tritium] + 35 mrem/year [Pu 239] = 75 mrem/year; average annual dose to maximally exposed individual) and consequently, below levels of public health concern. No adverse health effects are likely from cumulative, off site radiation exposures to LLNL releases of tritium, plutonium, and other radionuclides.

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* It is the opinion of ATSDR that the doses (CEDE) resulting from tritium exposure and plutonium exposure can be summed for time periods longer than a year. Our reasoning is based on the effective half-life of tritium. The effective half-life is a function of the biological excretion rate (half-life; approximately 10 days) and physical half-life (12.3 years). Because the body has such a rapid turnover of fluids, the effective half-life of tritium in the body is less than one year (<15 days for tritiated water [HTO] and < 1 year for organically bound tritium [OBT]). Thus any radiological dose resulting from exposure to tritium will impart its total dose in a period of less than one year. Modeling using ICRP information also indicates that the dose from any form of tritium absorbed into the body remains constant year after year following an intake. That is, the annual dose from tritium is essentially the CEDE. Therefore, summing the dose from tritium and plutonium is an acceptable approach for determining the total dose.

Conclusions, Recommendations, and the Public Health Action Plan

Conclusions

Based on the above findings, past and ongoing operations and releases from the LLNL facility, including the Naval Air Station previously on this site, are ***No Apparent Public Health Hazard***. This conclusion means that although community exposures to site-related contaminants may have occurred or may be occurring, the resulting doses are unlikely to result in any adverse health effects and are consequently below levels of public health concern. Past and current pathways of community exposure to LLNL –related contaminants are below levels of public health concern. The current environmental monitoring program conducted by LLNL is adequate to ensure that future releases of hazardous substances will not present a future public health hazard. This public health determination is based on the following conclusions:

- Releases of hazardous substances by LLNL (or the Naval Air Station that previously occupied the site) have resulted in the contamination of ground water, soil, surface water, air and biota in the Livermore community adjacent to the LLNL facility.

- Evaluation of the distribution and concentrations of those substances in the respective environmental media indicates that several contaminants (chromium-6, PCE, and TCE) are present in areas of potential community exposure at concentrations exceeding various environmental screening (comparison) values. Other contaminants above screening values (boron, chromium, manganese, and nitrate) may be present in areas of potential exposure due to naturally occurring background concentrations or non-LLNL specific agricultural contamination.

- LLNL has also released measurable quantities of Pu 239 (and associated radionuclides) and tritium into the environment. Previous assessments have determined that both short term and long term exposures to those radionuclides are below levels expected to produce any adverse health effects.

- In the past, community exposure to ground water contaminated by LLNL-specific contaminants (chromium-6, PCE, and TCE) was restricted to a few residences with private wells that were directly adjacent to the west boundary of the facility (circa 1983). Measured contaminant concentrations in those wells indicate that the past exposures are not expected to result in any adverse health effects. There is no current ground water exposure to site-related contamination as the affected wells have been destroyed. Ongoing ground water remediation is also reducing the potential for future exposure to LLNL-related ground water contaminants are other locations.

- Potential exposure to non-LLNL related ground water contaminants (boron, chromium, manganese, and nitrate) is ongoing. The concentrations of Pu 239, tritium, and other radionuclides in areas of potential off site exposure are below levels of public health concern in all pathways and environmental media.

- Potential ingestion of nitrate from ground water wells throughout the Livermore Valley may result in doses capable of producing adverse health effects. Based on the distribution of nitrate concentrations in monitor wells and an inactive drinking water well, estimates of the 95th percentile doses could represent a public health hazard. However, average and most likely doses are below levels of public health concern. Based on the distribution of elevated nitrate concentrations, the nitrate contamination is probably a result of widespread agricultural contamination and not related to the LLNL facility.

- Estimated health protective doses, including the potential for cumulative doses across pathways, for the above preliminary contaminants of concern are below health comparison values (health guidelines) for all contaminants except boron, nitrate, and PCE. Estimated doses for boron and PCE are more than 100 times lower than any doses that have associated with adverse health effects in human or animal studies. Similarly, estimated maximum annual cumulative doses to Pu 239 and tritium from LLNL releases in 1965 and 1970 are less than 1/3 of natural background radiation doses and not expected to cause any adverse health effects. Due to the health protective assumptions underlying these dose calculations, it is unlikely that members of the Livermore community were actually exposed to the maximum annual historic estimated doses and potential current exposures (less than 1 mrem/year) cannot be differentiated from the variation of natural background radiation.

Recommendations

- The current LLNL environmental monitoring program required for regulatory compliance with permitted air and water discharges should be continued to ensure that future community exposures to LLNL releases remain below levels of public health concern.

- Additional investigation of Livermore Valley private drinking water wells should be undertaken to ensure that areas of nitrate contamination (not related to LLNL releases or sources) are identified and that people are not drinking nitrate-contaminated water.

Public Health Action Plan

This Public Health Action Plan for the Main Site of the Lawrence Livermore National Laboratory describes the completed or planned public health actions undertaken by ATSDR, DOE, or other entities in the Livermore community. The purpose of this Action Plan is to ensure that this public health assessment provides a specific plan of action to prevent or mitigate adverse human health effects resulting from exposure to hazardous substances in the environment.

Public Health Actions Completed

- DOE currently monitors air, ground and surface water, soil, and biota, as required by regulatory compliance with permitted air and water discharges, and plans on continuing such monitoring for site-specific chemical and radioactive contaminants.

- ATSDR has provided technical and health information to community members, including fact sheets on specific contaminants and historic exposures, and will continue to do so, as requested.

Public Health Actions Planned

- If additional information concerning potential exposures or off site contaminant concentrations becomes available that potentially changes our public health findings, ATSDR will reevaluate the potential for adverse health effects from LLNL-specific sources or releases.

- The California Department of Health Services, Environmental Health Investigations Branch and the San Francisco Bay Regional Water Quality Control Board will address the recommendation for further evaluation of nitrate contamination (non-LLNL related) in the Livermore Valley.

Community members that are concerned about potential nitrate contamination of their drinking water wells should contact:

Alameda County Environmental Health
Drinking Water Program
1131 Harbor Bay Parkway
Alameda, CA 94502-6577
Telephone: (510) 567-6700

Additional information for homeowners with a private drinking water well is available from the National Ground Water Association (http://www.wellowner.org/) and includes specific information on nitrate contamination.

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Preparers of Report

Mark W. Evans, Ph.D.
Environmental Geologist
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation

Paul A. Charp, Ph.D.
Senior Health Physicist
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation

Reviewers of Report

Burt J. Cooper, M.S.
Supervisory Environmental Health Scientist
Energy Section Chief,
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation

Sandra G. Isaacs
Chief,
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation

Scott Sudweeks
Toxicologist
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation

Regional Representative

Gwendolyn Eng
Senior Regional Representative
Regional Services, Region IX
Office of Regional Operations

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Appendix 1. Glossary of Environmental Health Terms

Absorption: How a chemical enters a person's blood after the chemical has been swallowed, has come into contact with the skin, or has been breathed in.

Activity: The number of radioactive nuclear transformations occurring in a material per unit time. The term for *activity* per unit mass is specific activity.

Acute Exposure: Contact with a chemical that happens once or only for a limited period of time. ATSDR defines acute exposures as those that might last up to 14 days.

Additive Effect: A response to a chemical mixture, or combination of substances, that might be expected if the known effects of individual chemicals, seen at specific doses, were added together.

Adverse Health Effect: A change in body function or the structures of cells that can lead to disease or health problems.

Antagonistic Effect: A response to a mixture of chemicals or combination of substances that is **less** than might be expected if the known effects of individual chemicals, seen at specific doses, were added together.

ATSDR: The **A**gency for **T**oxic **S**ubstances and **D**isease **R**egistry. ATSDR is a federal health agency in Atlanta, Georgia that deals with hazardous substance and waste site issues. ATSDR gives people information about harmful chemicals in their environment and tells people how to protect themselves from coming into contact with chemicals.

Background Level: An average or expected amount or concentration range of a substance in a specific environment or, amounts that occur naturally in the-environment.

Background radiation: The amount of radiation to which a member of the general population is exposed from natural sources, such as terrestrial radiation from naturally occurring radionuclides in the soil, cosmic radiation originating from outer space, and naturally occurring radionuclides deposited in the human body.

Biota: Used in public health, things that humans would eat – including animals, fish and plants.

Body burden: The total amount of a substance in the body. Some substances build up in the body because they are stored in fat or bone or because they leave the body very slowly.

CAP: See **C**ommunity **A**ssistance **P**anel**.**

Cancer: A group of diseases which occur when cells in the body become abnormal and grow, or multiply, out of control

Carcinogen: Any substance shown to cause tumors or cancer in experimental studies.

CERCLA: See **C**omprehensive **E**nvironmental **R**esponse, **C**ompensation, and **L**iability **A**ct.

Chronic Exposure: A contact with a substance or chemical that happens over a long period of time. ATSDR considers exposures of more than one year to be *chronic*.

Committed Effective Dose Equivalent (CEDE): The sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to the organs or tissues integrated over a specified time period (such as 50 or 70 years). The *committed effective dose equivalent* is used in radiation safety because it implicitly includes the relative carcinogenic sensitivity of the various tissues. The unit of dose for the CEDE is the rem (or, in SI units, the sievert—1 sievert equals 100 rem.)

Completed Exposure Pathway: See **Exposure Pathway**.

Community Assistance Panel (CAP): A group of people from the community and health and environmental agencies who work together on issues and problems at hazardous waste sites.

Comparison Value: **(CVs)** Concentrations or the amount of substances in air, water, food, and soil that are, upon exposure, unlikely, to cause adverse health effects. Comparison values are used by health assessors to select which substances and environmental media (air, water, food and soil) need additional evaluation while health concerns or effects are investigated. See Appendix 4 for the derivation of CVs.

Comprehensive Environmental Response, Compensation, and Liability

Act (CERCLA): **CERCLA** was put into place in 1980. It is also known as **Superfund**. This act concerns releases of hazardous substances into the environment, and the cleanup of these substances and hazardous waste sites. ATSDR was created by this act and is responsible for looking into the health issues related to hazardous waste sites.

Concern: A belief or question about substances in the environment that might cause harm to people.

Concentration: How much or the amount of a substance present in a certain amount of soil, water, air, or food.

Contaminant: See **Environmental Contaminant**.

Contaminant of (public health) concern: An environmental contaminant for which, (1) environmental concentrations exceed media-specific comparison values, or (2) has noted community health concerns, or (3) the quality and extent of sampling data with which to evaluate potential exposure and human health hazard is inadequate.

Curie (Ci): A unit of radioactivity. One *curie* equals that quantity of radioactive material in which there are 3.7×10^{10} nuclear transformations per second. The activity of 1 gram of radium is approximately 1 Ci; the activity of 1.46 million grams of natural uranium is approximately 1 Ci.

Decay product, daughter product, progeny: A new nuclide formed as a result of radioactive decay: from the radioactive transformation of a radionuclide, either directly or as the result of successive transformations in a radioactive series. A *decay product* can be either radioactive or stable.

Delayed Health Effect: A disease or injury that happens as a result of exposures that may have occurred far in the past.

Dermal Contact: A chemical getting onto your skin. (see **Route of Exposure**).

Dose: The amount of a substance to which a person may be exposed, usually on a daily basis. Dose is often explained as "amount of substance(s) per body weight per day".

Dose (for radioactive chemicals): The radiation *dose* is the amount of energy from radiation that is actually absorbed by the body. This is not the same as measurements of the amount of radiation in the environment

Dose / Response: The relationship between the amount of exposure (dose) and the change in body function or health that result.

Duration: The amount of time (days, months, years) that a person is exposed to a chemical.

Environmental Contaminant: A substance (chemical) that gets into a system (person, animal, or the environment) in amounts higher than that found in **Background Level**, or what would be expected.

Environmental Media: Usually refers to the air, water, and soil in which chemcials of interest are found. Sometimes refers to the plants and animals that are eaten by humans. **Environmental Media** is the second part of an **Exposure Pathway**.

U.S. Environmental Protection Agency (EPA): The federal agency that develops and enforces environmental laws to protect the environment and the public's health.

Epidemiology: The study of the different factors that determine how often, in how many people, and in which people will disease occur.

Equilibrium, radioactive: In a radioactive series, the state that prevails when the ratios between the activities of two or more successive members of the series remain constant.

Exposure: Coming into contact with a chemical substance.(For the three ways people can come in contact with substances, see **Route of Exposure**.)

Exposure Assessment: The process of finding the ways people come in contact with chemicals, how often and how long they come in contact with chemicals, and the amounts of chemicals with which they come in contact.

Exposure Pathway: A model describing how a substance moves from its source (where it was released) to where and how people can come into contact with (or get exposed to) the chemical. ATSDR defines an exposure pathway as having

5 parts:

1. Source of Contamination,
2. Environmental Media and Transport Mechanism,
3. Point of Exposure,
4. Route of Exposure, and
5. Receptor Population.

When all 5 parts of an exposure pathway are present, it is called a **Completed Exposure Pathway**. Each of these 5 terms is defined in this Glossary.

Frequency: How often a person is exposed to a chemical over time; for example, every day, once a week, twice a month.

Half-life ($t_{½}$): The time it takes for half the original amount of a substance to decay or transform. In the environment, the *half-life* is the time it takes for half the original amount of a substance to change to another chemical form by bacteria, fungi, sunlight, or other chemical processes. In the human body, the *half-life* is the time it takes for half the original amount of the substance to change to another substance or by leave the body. In the case of radioactive material, the *half-life* is the amount of time necessary for one half the initial radioactive atoms to change or transform into other atoms (normally not radioactive). After two *half-lives,* 25% of the original radioactive atoms remain.

Hazardous Substance (Waste): Substances that have been released into the environment which could, under certain conditions, be harmful to people who come into contact with them.

Health Comparison Value: See Comparison Value.

Health Effect: ATSDR deals only with **Adverse Health Effects** (see definition in this Glossary).

Health Guideline: Doses such as MRLs and RfDs that are likely to be without any adverse health effects. Health guideline values are expressed in units of dose such as mg/kg/day or cancer risk values as inverse dose (mg/kg/day^{-1}).

Health Protective Dose: Doses calculated using health protective exposure factors and contaminant concentrations that are most likely greater than any real dose to a member of the community.

Indeterminate Public Health Hazard: The category is used in Public Health Assessment documents for sites where important information is lacking (missing or has not yet been gathered) about site-related chemical exposures.

Ingestion: Swallowing something, as in eating or drinking. It is a way a chemical can enter your body (See **Route of Exposure**).

Inhalation: Breathing. It is a way a chemical can enter your body (See **Route of Exposure**).

Ionizing radiation: Any radiation capable of knocking electrons out of atoms and producing ions. Examples: alpha, beta, gamma and x rays, and neutrons.

Isotopes: Nuclides having the same number of protons in their nuclei, and hence the same atomic number, but differing in the number of neutrons, and therefore in the mass number. Identical chemical properties exist in *isotopes* of a particular element. The term should not be used as a synonym for "nuclide," because "isotopes" refers specifically to different nuclei of the same element.

LOAEL: **L**owest **O**bserved **A**dverse **E**ffect **L**evel. The lowest dose of a chemical in a study, or group of studies, that has caused harmful health effects in people or animals.

Malignancy: See **Cancer**.

MRL: **M**inimal **R**isk **L**evel. An estimate of daily human exposure – by a specified route and length of time -- to a dose of chemical that is likely to be without a measurable risk of adverse, noncancerous effects. An MRL should not be used as a predictor of adverse health effects.

NPL: The **N**ational **P**riorities **L**ist. (Which is part of **Superfund**.) A list kept by the U.S. Environmental Protection Agency (EPA) of the most serious, uncontrolled or abandoned hazardous waste sites in the country. An NPL site needs to be cleaned up or is being looked at to see if people can be exposed to chemicals from the site.

NOAEL: **N**o **O**bserved **A**dverse **E**ffect **L**evel. The highest dose of a chemical in a study, or group of studies, that did not cause harmful health effects in people or animals.

No Apparent Public

Health Hazard: The category is used in ATSDR's Public Health Assessment documents for sites where exposure to site-related chemicals may have occurred in the past or is still occurring but the exposures are not at levels expected to cause adverse health effects.

No Public Health Hazard: The category is used in ATSDR's Public Health Assessment documents for sites where there is evidence of an absence of exposure to site-related chemicals.

Parent: A radionuclide which, upon disintegration, yields a new nuclide, either directly or as a later member of a radioactive series.

PHA: **P**ublic **H**ealth **A**ssessment. A report or document that looks at chemicals at a hazardous waste site and tells if people could be harmed from coming into contact with those chemicals. The PHA also tells if possible further public health actions are needed.

Plume: A line or column of air or water containing chemicals moving from the source to areas further away. A plume can be a column or clouds of smoke from a chimney or contaminated underground water sources or contaminated surface water (such as lakes, ponds and streams).

Point of Exposure: The place where someone can come into contact with a contaminated environmental medium (air, water, food or soil). For examples: the area of a playground that has contaminated dirt, a contaminated spring used for drinking water, the location where fruits or vegetables are grown in contaminated soil, or the backyard area where someone might breathe contaminated air.

Population: A group of people living in a certain area; or a group of individual persons, or objects from which samples are taken for statistical measurements.

PRP: **P**otentially **R**esponsible **P**arty. A company, government or person that is responsible for causing the pollution at a hazardous waste site. PRP's are expected to help pay for the clean up of a site.

Public Health Assessment(s): See **PHA**.

Public Health Hazard: The category is used in ATSDR documents for sites that have certain physical features or evidence of chronic, site-related chemical exposure that could result in adverse health effects.

Public Health

Hazard Criteria: PHA categories given to a site which tell whether people could be harmed by conditions present at the site. Each are defined in the Glossary. The categories are:
- Urgent Public Health Hazard
- Public Health Hazard
- Indeterminate Public Health Hazard
- No Apparent Public Health Hazard
- No Public Health Hazard

Quality factor (radiation weighting factor): The linear-energy-transfer-dependent factor by which absorbed doses are multiplied to obtain (for radiation protection purposes) a quantity that expresses - on a common scale for all ionizing radiation - the approximate biological effectiveness of the absorbed dose.

Rad: The unit of absorbed dose equal to 100 ergs per gram, or 0.01 joules per kilogram (0.01 gray) in any medium [see dose].

Receptor Population: People who live or work in the path of one or more chemicals, and who could come into contact with them (See **Exposure Pathway**).

Reference Dose (RfD): An estimate, with safety factors (see **safety factor**) built in, of the daily, life-time exposure of human populations to a possible hazard that is <u>not</u> likely to cause harm to the person.

Rem: A unit of dose equivalent. The dose equivalent in rem is numerically equal to the absorbed dose in rad multiplied by the quality factor. Rem is used only in the context of radiation safety, administrative, and engineering design purposes.

Route of Exposure: The way a chemical can get into a person's body. There are three exposure routes:
- breathing (also called inhalation),
- eating or drinking (also called ingestion), and
- or getting something on the skin (also called dermal contact).

Safety Factor: Also called **Uncertainty Factor**. When scientists don't have enough information to decide if an exposure will cause harm to people, they use "safety factors" and formulas in place of the information that is not known. These factors and formulas can help determine the amount of a chemical that is <u>not</u> likely to cause harm to people.

SARA: The **S**uperfund **A**mendments and **R**eauthorization **A**ct in 1986 amended

CERCLA and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from chemical exposures at hazardous waste sites.

Sample: A representative individual or item from a larger group or population, or finite part of a statistical population.

Source (of Contamination): The place where a chemical comes from, such as a landfill, pond, creek, incinerator, tank, or drum. Contaminant source is the first part of an Exposure Pathway.

Special Populations: People who may be more sensitive to chemical exposures because of certain factors such as age, a disease they already have, occupation, sex, or certain behaviors (like cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Statistics: A branch of the math process of collecting, looking at, and summarizing data or information.

Superfund Site: See **NPL**.

Survey: A way to collect information or data from a group of people (**population**). Surveys can be done by phone, mail, or in person. ATSDR cannot do surveys of more than nine people without approval from the U.S. Department of Health and Human Services.

Synergistic effect: A health effect from an exposure to more than one chemical where the combined effect of the chemicals together is greater than the effects of the chemicals acting by themselves.

Toxic: Harmful. Any substance or chemical can be toxic at a certain dose (amount). The dose is what determines the potential harm of a chemical and whether it would cause someone to get sick.

Toxicology: The study of the harmful effects of chemicals on humans or animals.

Tumor: Abnormal growth of tissue or cells that have formed a lump or mass.

Uncertainty Factor: See **Safety Factor**.

Urgent Public Health Hazard: This category is used in ATSDR's documents for sites that have certain physical features or evidence of short-term (less than 1 year), site-related chemical exposure that could result in adverse health effects and require quick intervention to stop people from being exposed.

Appendix 2. Summary of Public Health Assessment on "Community Exposures to the 1965 and 1970 Accidental Tritium Releases"

http://www.atsdr.cdc.gov/HAC/PHA/livermore4/lms_toc.html

Summary

The Lawrence Livermore National Laboratory (Livermore site, hereafter referred to as LLNL) is a multi-program research facility owned by the U.S. Department of Energy (DOE) and operated by the University of California. LLNL was placed on the Superfund National Priority List (NPL) in 1987. The Agency for Toxic Substances and Disease Registry (ATSDR) is required to conduct a public health assessment of all facilities proposed for listing on the NPL. During the LLNL public health assessment process, potential off site exposure to tritium released by LLNL has been identified as a specific community concern (CDHS 2003). In response to this concern, ATSDR convened an expert panel to assess tritium monitoring and dosimetry issues at the Lawrence Livermore National Laboratory (LLNL) and Savannah River Site (SRS) facilities. Although the expert panel determined that approximately 80% of the total radiologic releases from the LLNL facility occurred during two accidents in 1965 and 1970, they did not explicitly evaluate potential short-term tritium doses from those accidental releases. This public health assessment will specifically evaluate potential short-term tritium doses from the accidental tritium releases to determine whether these releases presented a public health hazard to members of the Livermore community.

There are insufficient historic environmental sample data available to adequately evaluate the total tritium doses from these releases. Consequently, this evaluation will use modeled data combined with available measured data to estimate past exposure concentrations and doses. This evaluation focuses on exposure doses to maximally exposed individuals. Available meteorological data indicate that for the 1965 release winds were blowing to the east-northeast at about 3 meters per second (m/s). The maximally exposed residence is more than 1 mile from the tritium facility for the 1965 release (January 20, 1965) with an estimated maximum of 18 people living in the plume area to a distance of 2 miles from the tritium facility. During the 1970 release, winds were blowing to the north-northeast at about 1.5 m/s and the closest residence was also more than 1 mile from the tritium facility. An estimated maximum of 55 people were living in the area of the 1970 plume to a distance of 2 miles from the tritium facility.

Tritium is a radioactive isotope of hydrogen. As hydrogen, tritium might be present in the environment as any chemical form or compound of hydrogen, including hydrogen gas (HT), tritiated water (HTO), or as various organic compounds (known generically as organically bound tritium; OBT). The specific absorbed dose from tritium exposure depends on the chemical form of the tritium that is ingested or inhaled or absorbed. The radiologic dose is determined by how many tritium decays occur in the body after intake. As hydrogen gas, very little tritium is absorbed and retained in the body following exposure. Consequently, very few tritium decays occur in the body from HT inhalation. Conversely, most of the tritium taken in as water or HTO (including a lesser OBT contribution) is absorbed and retained in the body with an effective half-life that varies from 1 to about 40 days.

Both of the accidental tritium releases from LLNL occurred in the HT form. Consequently, there is very little radiologic dose from direct inhalation of the HT plumes. However, HT is converted by soil microbes into the HTO form of tritium. Subsequent exposure to HTO creates the potential for much more significant radiologic doses. This health assessment is based on potential exposures to each of the significant tritium forms as it moves through the environment. As there are insufficient environmental measurements of each of the tritium forms in air following the accidental releases, this health assessment relies on air dispersion and exposure models to evaluate potential historic short-term tritium exposures. Specifically, this assessment uses the RASCAL air dispersion model to determine concentrations of airborne HT in areas of potential exposure. The Industrial Source Complex air model is used to estimate concentrations of HTO in areas of potential exposure due to emission of HTO from the soil. To accommodate the uncertainty inherent in each of these modeling steps, a Monte Carlo simulation is conducted to determine the most likely tritium doses from each type of exposure.

The estimated total tritium doses include direct inhalation of the HT plumes, inhalation of HTO following emission from soil, direct absorption of HTO through skin, ingestion of foods containing HTO and OBT, and also sum potential chronic exposures from ongoing (past) LLNL tritium releases. The estimated maximum doses (to a child; 95th percentile) are less than 149 millirem/year (mrem/year) for both the 1965 and 1970 releases. The more likely average doses are about 42 mrem/year. On the basis of current peer-reviewed scientific literature, the one-time exposure to tritium resulting in a committed effective adult dose of 42 mrem (0.42 mSv) or a child dose of 149 mrem (1.49 mSv) from the LLNL accidental HT releases is not expected to be a public health hazard.

While some public exposure to tritium probably did occur as a result of the accidental releases of tritium gas (HT), estimated maximum exposures are below levels of public health concern and no adverse health effects would be expected. This conclusion is based on tritium doses developed from analytical models and is supported by human biological samples that showed no detectable tritium from either LLNL workers or affected community members. The above doses represent the 95th percentile doses on the basis of health protective exposure and dosimetry assumptions. It is unlikely that actual doses approached these conservatively estimated values.

All of the adverse health effects from exposures to tritium (or low-energy external gamma radiation or x-rays) that we found in the medical literature occurred at levels higher than the exposure levels we estimated for people living near the LLNL facility at the time of the accidental releases. Therefore, we conclude that inhalation and ingestion of tritium from the acute releases that occurred in 1965 and 1970, plus the annual contribution from chronic or long-term exposures, were never a public health hazard. Because these historic accidental releases are below levels of public health concern, no specific recommendations are warranted.

Appendix 3. Summary of Public Health Assessment on "Plutonium 239 in Sewage Sludge Used as a Soil or Soil Amendment in the Livermore Community"

http://www.ci.livermore.ca.us/CADHS/ATSDR_PHA_2-11-2003.pdf

Summary

Potential off site exposure to plutonium 239 (Pu 239) in sewage sludge released from the Lawrence Livermore National Laboratory (LLNL) to the Livermore Water Reclamation Plant (LWRP) has been identified as a specific community concern. This public health assessment will address that concern by evaluating the public health implications of potential radiological doses from exposures to the Pu 239-contaminated sludge. In order to evaluate the public health implications of the historical distribution of Pu-contaminated sludge to the Livermore community three specific questions are addressed: 1) What concentrations of Pu 239 in sludge would produce doses of public health concern? 2) Were the concentrations of Pu 239 in the sludge distributed to the public by LWRP greater than the levels of potential health concern? 3) Do the available data provide an adequate basis for this public health assessment?

Doses of public health concern are defined as the human intake of Pu 239 (or other radionuclides) via ingestion, inhalation, or external exposure at levels that are capable of causing adverse health effects, such as cancer, other illnesses, or death. The ATSDR minimal risk level (MRL) of 100 mrem/year (above background) is used as a basis for determining radiological doses of public health concern. No adverse health effects have ever been documented from radiological doses of 100 mrem/year or less (above background). The average background radiation dose throughout the US is about 360 mrem/year. The MRL represents a dose of less than 1/3 of normal background.

Several sources of historical monitoring data are available to assess the historic concentrations of Pu 239 in sludge produced at the LWRP. These data include gross alpha concentrations in LLNL effluent to the LWRP, gross alpha concentrations in both digester and processed sludge, and Pu 239 concentrations in soils of disposal areas for contaminated sludge. Past studies have evaluated the potential radiological doses from exposure to Pu 239-contaminated sludge. These studies have assumed different exposure scenarios, including LWRP workers responsible for tilling and spreading the contaminated sludge, residents living adjacent to the sludge disposal area, children playing in sludge-contaminated areas, and adults gardening in and consuming food crops grown in contaminated-sludge soils.

The Pu 239-contaminated sludge, released from the LLNL to the LWRP, and distributed to the Livermore community represents a completed exposure pathway. The route or process of human uptake of the Pu 239 occurs via incidental ingestion and inhalation during the use, transport, or handling of the sludge, or the soil where the sludge was placed, or ingestion of vegetation grown in the sludge-amended soil. The calculation of radiological doses from a long-lived isotope such as Pu 239 is very complex due to the partitioning, retention, and decay of the isotope and each of its decay products within the environment and the different organs in the human body. For this

health assessment, radiological doses from exposure to the Pu 239 contaminated sludge are calculated using RESRAD 6.2.1**.**

A soil Pu 239 concentration (100 percent sludge cover) of 816 pico Curies per gram (pCi/g; 1 pCi=1x 10^{-12} curies; averaged over an entire exposure area or residential yard) is required to produce a dose of 100 mrem/year, as calculated using RESRAD. This calculation includes health-protective exposure factors and includes ingestion of soil and garden crops, inhalation of dust, and external exposure. This calculation also assumes that the contaminated area covers an area of ½ acre to a depth of 6 feet, ½ of the area is unvegetated, and ½ of the resident's food is grown on the contaminated area. Considering that it would take 108 pick-up truck loads of sludge to cover a 1/2 acre lot (to a 3 inch depth), such an exposure scenario, although possible, is very unlikely.

A nearly complete historical record of LWRP gross alpha concentrations for the period of 1960 through 1973 (analyzed by the California Department of Public Health; CDPH) indicates that maximum digester sludge concentrations were less than 300 pCi/g (monthly average values). The average monthly gross alpha concentration of digester sludge measured by LLNL was 606 pCi/g (June 1967; average of digesters 1 and 2). The CDPH digester sludge values show two distinct peaks corresponding with the 1964 and 1967 release episodes (297 pCi/g and 258 pCi/g, CDPH data, respectively). Gross alpha concentrations of LLNL effluent into the Livermore sewer system show the same peaks and provide supplementary data for those periods during which digester concentrations were not collected or analyzed. Collectively, the measured digester sludge data and the LLNL analyzed effluent data indicate that the 1964 and 1967 release episodes represent the worst-case sludge concentrations.

As the concentrations of Pu 239 in processed sewage sludge following the 1964 episode of maximum digester sludge concentration were less than 816 pCi/g, it follows that the maximum Pu 239 concentrations in sludge were below levels of health concern. Although sludge concentrations following the 1967 event are not available, processed sludge gross alpha concentrations following the 1964 release (297 pCi/g digester sludge values) were approximately 60 pCi/g. This indicates that digester sludge gross alpha concentrations are considerably reduced during the treatment process. As processed sludge is further milled and mixed before disposal, it is expected that processed sludge concentrations would be additionally reduced before distribution to the public.

Several areas where contaminated sludge was placed have been sampled for Pu 239 concentrations. These areas include Big Trees Park, residential yards of former LLNL employees, and a test garden on the LLNL facility. Maximum Pu 239 concentrations of these locations were less than 2 pCi/g. Although the initial sludge concentration of most of these areas is unknown, sludge and soil sampling at the LLNL test garden indicated that Pu 239 concentrations in applied sludge are reduced by a factor of more than 5 in the resulting soil. This indicates that tilling and mixing of applied sludge will additionally reduce residential soil Pu 239 concentrations.

Assuming that the available gross alpha concentrations in LWRP sludge and LLNL sewer effluent are a reasonable substitute for direct Pu 239 measurements, the available data clearly indicate that

the Pu 239-contaminated sludge does not result in radiological doses of public health concern. Monthly nuclide specific and gross alpha monitoring data for 1973 indicate that gross alpha concentrations overestimate Pu 239 concentrations. Consequently, the use of gross alpha concentrations as a proxy for Pu 239 concentrations is a health protective assumption.

No single data set is adequate for making the above public health determinations. There is not a consistent time series of Pu 239 or gross alpha concentrations in processed sludge. Similarly, there are gaps in the digester sludge measurements, and the LLNL effluent data do not provide specific levels of sludge contamination. However, collectively, the available data do provide an adequate basis for public health assessment. The trends in the different data values support and reinforce the individual data sets. Additionally, the health protective assumptions used in calculating doses provide additional assurance for the health conclusions. The following conclusions are based on our current knowledge of radiation health effects and the data reviewed and evaluated in this health assessment:

1. Pu 239 from LLNL was released to the Livermore sewer system and resulted in the contamination of LWRP sludge which may have been distributed to the Livermore community resulting in areas of above background soil concentrations of Pu 239.
2. Using health protective exposure assumptions, radiological doses from maximum measured concentrations of digester sludge are below levels of health concern. This evaluation assumes that digester sludge gross alpha concentrations represent Pu 239 concentrations and that digester sludge is spread uniformly over an entire residential yard. Pu 239 concentrations of processed sludge distributed to the Livermore community are estimated to be more than 10 times lower than digester sludge concentrations.
3. The available data and evaluations provide an adequate basis for these public health conclusions. Any additional sampling data will be subject to the same types of uncertainties as existing historical data.

Based on the above conclusions, the historic distribution of Pu-contaminated sewage sludge is determined to be **no apparent public health hazard**. No apparent public health hazard means that while exposure may have occurred, or may still be occurring, the resulting doses are unlikely to cause cancer, other illnesses, or death. As the potential maximum radiological doses from exposures to Pu 239-contaminated sludge are below levels of health concern, ATSDR has no recommendations concerning additional soil sampling in areas of known or unknown sludge distribution. Because the community may still have unresolved concerns about this issue, ATSDR offers the following recommendations:

1. Develop and present educational materials, based on the information included in this public health assessment, to the Livermore community.
2. Continue current monitoring of Pu 239 (and other contaminant) concentrations in LLNL effluent and the LWRP sewage treatment system (as stipulated by existing discharge permit requirements).

Appendix 4. Health Guidelines, Comparison Values, and Exposure Factors

When a hazardous substance is released to the environment, people are not always exposed to it. Exposure happens when people breathe, eat, drink, or make skin contact with a contaminant. People can also be exposed to radioactive contaminants by direct irradiation—if they get close to the radioactive material and if the contaminants are present at high concentrations.

Several factors determine the type and severity of health effects associated with exposure to contaminants. Such factors include exposure concentration, frequency and duration of exposure, route of exposure, and cumulative exposures (i.e., the combination of contaminants and routes). Once exposure takes place, individual characteristics—such as age, sex, nutritional status, genetics, lifestyle, and health status—influence how that person absorbs, distributes, metabolizes, and excretes the contaminant. These characteristics, together with the exposure factors discussed above and the specific toxicological effects of the substance, determine the health effects that may result.

ATSDR considers these physical and biological characteristics when developing health guidelines. Health guidelines provide a basis for evaluating exposures estimated from concentrations of contaminants in different environmental media (soil, air, water, and food) depending on the characteristics of the people who may be exposed and the length of exposure. Health guideline values are in units of dose such as milligrams (of contaminant) per kilogram of body weight per day (mg/kg/day).

ATSDR reviews health and chemical information in documents called toxicological profiles. Each toxicological profile covers a particular substance; it summarizes toxicological and adverse health effects information about that substance and includes health guidelines such as ATSDR's minimal risk level (MRL), EPA's reference dose (RfD) and reference concentration (RfC), and EPA's cancer slope factor (CSF). ATSDR public health professionals use these guidelines to determine a person's potential for developing adverse non-cancer health effects and/or cancer from exposure to a hazardous substance.

An MRL is an estimate of daily human exposure to a contaminant that is likely to be without an appreciable risk of adverse non-cancer health effects over a specified duration of exposure (acute, less than 15 days; intermediate, 15 to 364 days; chronic, 365 days or more). Oral MRLs are expressed in units of milligrams per kilogram per day (mg/kg/day); inhalation MRLs are expressed in micrograms per cubic meter ($\mu g/m^3$). MRLs are not derived for dermal exposure.

RfDs and RfCs are estimates of daily human exposure, including exposure to sensitive subpopulations that are likely to be without appreciable risk of adverse non-cancer health effects during a lifetime (70 years). These guidelines are derived from experimental data and lowest-observed-adverse-effect levels (or no-observed-adverse-effect levels), adjusted downward using uncertainty factors. The uncertainty factors are used to make the guidelines adequately protective of public health. RfDs and RfCs should not be viewed as strict scientific boundaries between what is toxic and what is nontoxic.

For cancer-causing substances, EPA established the cancer slope factor (CSF; EPA 2004). A CSF is used to determine the number of excess cancers expected from maximal exposure for a lifetime.

Health comparison values (CVs) are estimated contaminant concentrations that are unlikely to cause detectable adverse health outcomes when these concentrations occur in specific media. CVs are used to select site contaminants for further evaluation. CVs are calculated from health guidelines and are presented in media specific units of concentration, such as micrograms/liter (μg/l) or ppm. CVs are calculated using conservative assumptions about daily intake rates by an individual of standard body weight. Because of the conservatism of the assumptions and safety factors, contaminant concentrations that exceed comparison values for an environmental medium do not necessarily indicate a health hazard.

For nonradioactive chemicals, ATSDR uses comparison values like environmental media evaluation guides (EMEGs), cancer risk evaluation guides (CREGs), reference dose (or concentration) media evaluation guides (RMEGs), and others. EMEGs, since they are derived from MRLs, apply only to specific durations of exposure. Also, they depend on the amount of a contaminant ingested or inhaled. Thus, EMEGs are determined separately for children and adults, and also separately for various durations of exposure. A CREG is an estimated concentration of a contaminant that would likely cause, at most, one excess cancer in a million people exposed over a lifetime. CREGs are calculated from CSFs. Reference dose (or concentration) media evaluation guides (RMEGs) are media guides based on EPA's RfDs and RfCs.

EPA's maximum contaminant levels (MCLs) are maximum contaminant concentrations of chemicals allowed in public drinking water systems. MCLs are regulatory standards set as close to health goals as feasible and are based on treatment technologies, costs, and other factors.

For radiological contaminants, ATSDR uses information on radiation exposure and its effects prepared by federal agencies, including EPA, DOE, and the US Nuclear Regulatory Commission. The agency also uses other publicly available data sources and recommendations on radiation dose limits. The National Council on Radiation Protection and Measurements (NCRP), the International Commission on Radiological Protection (ICRP), and the United Nations Scientific Committee on the Effects of Atomic Radiation are a few of the sources.

ATSDR uses standard or site specific intake rates for inhalation of air and ingestion of water, soil, and biota. These intake rates are specified in the pathway specific sections of the PHA. The dose calculation equations, and our assumptions about exposure factors, are derived from the ATSDR Public Health Assessment Guidance Manual (ATSDR 1992a) or from the EPA Exposure Factors Handbook (EPA 1999). For screening purposes, ATSDR often uses a health protective estimate of the maximum contaminant concentration (95^{th} percentile or maximum measured concentration) detected in a specific medium at a site to identify contaminants requiring specific exposure evaluations; using the maximum concentration results in a more protective evaluation. When unknown, the biological absorption of a substance within the human body is assumed to be 100%.

Doses calculated using health protective exposure factors and environmental concentrations are considered “health protective doses” because it is unlikely that any real community exposures are greater than the calculated doses and are most likely to be less than the health protective doses.

After estimating the potential exposure at a site, ATSDR identifies the site’s “contaminants of concern” by comparing the exposures of interest with health guidelines, or contaminant concentrations with comparison values. As a general rule, if the guideline or value is exceeded, ATSDR evaluates exposure to determine whether it is of potential health concern. Sometimes additional medical and toxicological information may indicate that these exposures are not of health concern. In other instances, exposures below the guidelines or values could be of health concern because of interactive effects with other chemicals or because of the increased sensitivity of certain individuals. Thus additional analysis is necessary to determine whether health effects are likely to occur.

Exposure doses via ingestion are calculated on the basis of the following equation:

Dose (Ingestion) = (Chemical Conc. x IR x EF x ED) / (BW x AT)

Where:

Chemical Conc.	= concentration of each contaminant (in mg/g, μg/g, mg/L, or μg/L)
IR	= ingestion rate (in grams/day or liters/day)
EF	= exposure frequency in days per year
ED	= exposure duration in years
BW	= body weight in kilograms
AT	= averaging time in days

For soil and sediment doses, we take an additional step to determine exposure via dermal absorption, with the total dose being the sum of the ingestion dose and the dermal dose.

Dose (Dermal) = (Chemical Conc. x ABS x TSA x EF x ED) / (BW x AT)

Where all factors are as above except:

ABS	= a chemical-specific absorption or bioavailability factor (unitless)
TSA	= total soil adhered in milligrams (skin surface area x soil adherence value)

Once we have calculated the dose (in mg/kg/day) for a contaminant, we evaluate that contaminant's non-cancer and cancer health effects. For the former, we compare the dose with studies that have investigated the health effects of exposure to the contaminant. For the latter, we multiply the dose by the pathway-specific CSFs which are expressed in units of inverse dose—that is, $(mg/kg/day)^{-1}$.

$$\textbf{Excess Cancer Risk} = \textbf{Dose (mg/kg/day)} \times \textbf{Cancer Slope Factor (mg/kg/day)}^{-1}$$

The excess cancer risk is the expected increase in cancer risk due to contaminant exposure. All of the uncertainties and health-protective exposure assumptions associated with the dose calculations are included in the risk estimation, as well as the uncertainty in deriving the CSF.

Appendix 5. Background Data and Procedures Related to Evaluation of Ground Water Contaminants

Estimated Contaminant Concentrations for Past Ground Water Exposures

Volatile organic compound (VOC) contamination in ground water was discovered at LLNL in 1983. Twenty off site wells were sampled for VOCs in December 1983 with detectable concentrations in eight wells and four wells had concentrations exceeding drinking water guidelines (Weiss Associates, 1985). Residents were provided bottled water and several residences were later plumbed to the Livermore water system (Weiss Associates, 1985; Hoffman, 2000). This Appendix will evaluate the measured VOC distributions and trends to determine whether concentrations prior to 1983 could have been higher than the post-1983 measured values, and if so, provide estimates of the maximum concentrations and durations of exposure.

Several VOCs were detected in those analyses with only PCE and TCE exceeding ATSDR health comparison values. This evaluation will focus on PCE and TCE, however, it will also compare trends and distributions of other detected VOCs to determine if prior concentrations may have exceeded ATSDR health comparison values. In addition to TCE and PCE, boron, chromium, chromium-6, manganese, and nitrate have also been identified as contaminants of concern (Section 2). Even though these contaminants may result from off site or natural sources, it is necessary to determine if potential exposures were at levels of public health concern. Consequently, the distributions of all contaminants of concern will be evaluated to determine the highest probable exposure doses and exposure durations.

Boron, chromium (total), manganese, and nitrate have either high background concentrations or have multiple off site sources such that areas of high concentration are widely distributed and do not have a distinct LLNL source. There has also been less frequent monitoring of these contaminants such that most wells do not have a consistent time-series of analytical results. Upper-bound concentrations for calculating exposure doses are based on the 95th percentile of both on and off site data values (Table A-1). A lifetime (70 year) exposure duration is assumed for these non site specific contaminants.

Hexavalent chromium also appears to have multiple on site and off site sources but high concentrations are assumed to be site-related due to its use and release from the LLNL cooling system. However, the most significant concentrations of off site chromium-6 are located in the vicinity of the Arroyo Los Positas plume and may be due to an off site source. The upper-bound concentration for calculating exposure doses is based on the 95th percentile of both on and off site data values (Table A-1). Because exposure may be related to LLNL releases, the chromium-6 exposure duration cannot exceed the operational history of LLNL and is assumed to be 30 years.

Estimation of PCE and TCE exposure concentrations and durations is problematic due to the truncated nature of the monitoring data. No measured contaminant concentrations are available prior to 1983. For this health assessment, measured contaminant concentrations along the down-

-gradient trend of the contaminant plumes will be used to estimate upper bounds for calculating maximum potential exposure doses.

Health-conservative variables for all parameters such as ingestion amounts, duration of exposure, and proportion of water from the contaminated wells will be used in all calculations. Estimation of contaminant concentrations prior to establishment of measurements will be accomplished by including measured contaminant values from on site wells that are closer to the contaminant sources than off site drinking water wells. Exposure doses will be calculated from the 95th percentile distribution (lognormal probability distribution) of measured contaminant concentrations. This procedure assumes that the maximum contaminant concentration in a down-gradient drinking water well cannot be higher than the measured concentrations in up-gradient wells closer to the contaminant sources. If the worst-case exposure estimates from this procedure identify exposures of health concern, additional dose evaluation techniques will be employed.

PCE and TCE have different off site concentrations distributions as illustrated in Figures A-2 and A-3 (respectively). While TCE is much more widespread and has higher on site concentrations than PCE, the primary off site TCE plume is located along Arroyo Los Positas and probably originates in the industrial park north and west of Vasco and Patterson Pass Roads. A smaller, lower concentration plume that originates from an LLNL source, joins or underlies the off site plume (these plumes may be vertically separated with the LLNL plume underlying the Richmond Lox plume). Another LLNL-originated TCE plume occurs in the vicinity of Arroyo Seco north and west of Vasco Road and East Avenue. Figure A-3 shows the annual maximum concentrations of TCE in a number of residential and monitor wells (note that the concentration or “Y” axis uses a logarithmic scale).

Rapidly increasing and then decreasing TCE concentrations with a maximum of 110 ppb (in 1985) occur in the Zone 7 monitor well 11A1. Concentrations in other wells are less than 40 ppb but in several wells the annual trend is decreasing at the time that monitoring began (i.e., wells 11R81, W-109, and W-143). Contaminant trends after 1989 reflect the installation and operation of extraction wells used to pump and treat the contaminated ground water. Several other wells have an intitally increasing trend of maximum TCE concentrations (W-001A, W-002, and W-143), however, the increasing trend in W-143 may reflect the influence of the remedial extraction wells. Even though there are no drinking water wells located in the vicinity of the Arroyo Los Positas plume, TCE concentrations from Zone 7 monitor well 11A1 are included in the calculation of the TCE probability distribution to ensure that potentially higher pre-1983 values are represented. Note that annual maximum values from wells W-001, W-001A, and W-143 are much lower than well 11A1 values and do not show consistent increasing or decreasing trends. The geometric mean of all TCE values plotted in Figure A-3 is 5.6 ppb and the 95th percentile value is 45.2 ppb which will be used in estimating exposure doses.

PCE concentrations at wells along the Arroyo Seco plume are shown in Figure A-2 and include all of the wells with known exposure (Table A-2). Well 11R5 (11R81) is the off site well with the highest measured PCE value. Note that concentration trends for wells 11J2 and 11R5 are decreasing after 1983 which suggests that concentrations before 1983 may have been higher. The trends for 11Q2 and 11Q3 which are located down-gradient of 11R5 are increasing after 1983 which indicates that the plume maxima from well 11R81 had not reached 11Q2/3 by 1983. PCE concentrations at the maximum on site source location, well W-116, are stable to slightly increasing during the 1980s. This suggests that pre-1983 PCE concentrations at the off site residential wells, including well 11R5, were not significantly higher than measured, post 1983 values. PCE doses are estimated from the well 11R5 concentrations. The geometric mean of all well 11R5 PCE values (Table A-2) is 241 ppb and the 95th percentile value is 511 ppb which is greater than the highest measured concentration (490 ppb).*

The PCE and TCE concentration trend data included in Figures A-2 and A-3 do not provide conclusive evidence concerning the potential durations of exposure. Although both figures show some wells with apparent pulses of higher concentrations, it is also possible that lower concentrations may have been present for many years. Considering that the primary VOC sources may have occurred from activities of the World War II-era Livermore Air Station, a worst-case estimate of 30 years exposure duration will be used for calculating PCE and TCE exposure doses.

Table A-1. Concentrations and potential exposure durations for preliminary contaminants of concern for the ground water pathway.

Contaminant	Geometric Mean ppb	95th Percentile ppb	Exposure Duration
Benzene	34	1,034	30 yrs.
Boron	733	3,097	Lifetime (70 yrs.)
Chromium (total)	21	83	Lifetime (70 yrs.)
Chromium (hexaval.)	23	75	30 yrs.
Manganese	138	2,009	Lifetime (70 yrs.)
Nitrate	21,318	80,121	Lifetime (70 yrs.)
PCE	241	511	30 yrs.
TCE	6	45	30 yrs.

* The on site wells W-116 and W-1107 (Figures A-1, A-2) had higher PCE concentrations than the down-gradient 11R5 well. However, both wells were located in the PCE source area and were screened at shallower and more restricted depths than 11R5 (86-91 and 74-88 feet vs. 125-325 feet, respectively). Because the PCE source monitor wells were specifically located to find the maximum PCE source concentrations, it is very unlikely that well 11R5, which was designed to maximize water production, ever had similar PCE concentrations.

Table A-2. Measured PCE concentrations in off site residential wells (ppb). < symbol indicates non-detections. Note that well 11R5 had the highest concentrations and was destroyed in 1987.

Well #	1983	1984	1985	1986	1987	1988	1989	1990	1991	1997
11A1	<1		<0.5 <0.5 <0.5 <0.5	<0.5 <0.5 <0.5 <0.5 1.6 1.7	0.7 <0.5 0.7	<0.5				
11J1	<1		<1 <0.5 <1 <0.5 <0.5 <1 <0.5 <0.5 <0.5 <0.5	<0.5 <0.5 <0.5 <0.5 <0.5 <0.5	<0.5 <0.5 <0.5	<0.5				
11J2	100	48	23 22 19	20 26 17 8.9	21 15 12	8.8 6.2	5.7 7.8	4.5 4.4	3.4	<0.5 <0.5
11Q2	2	3	2.4 3.3 4.5 3.2 1.5	4.5 4.2 4.5 6.6 4.8	5.8 4.8 5.7 86	14 28				
11Q3	<1	<1	2.4 3.7 8.7 18 83	15 14 17 19	18 29 69					
11R5	490 310	200 270 250 110	210							

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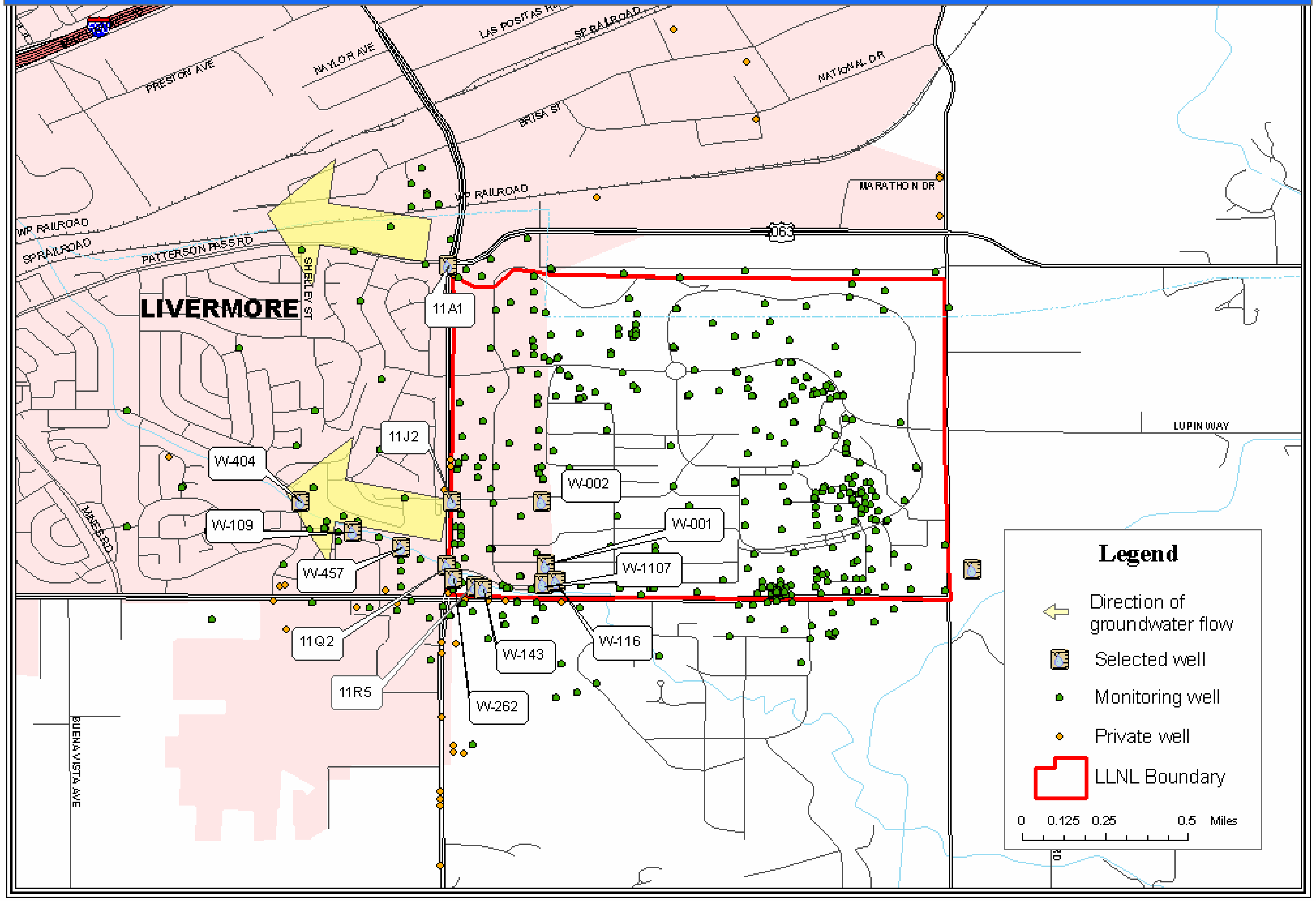
Figure A-1. Locations of private and monitor wells used to assess LLNL-specific ground water contamination. PCE and TCE concentrations from the labeled wells are presented in Figures A-2 and A-3. Available information on the private wells is presented in Table A-2.



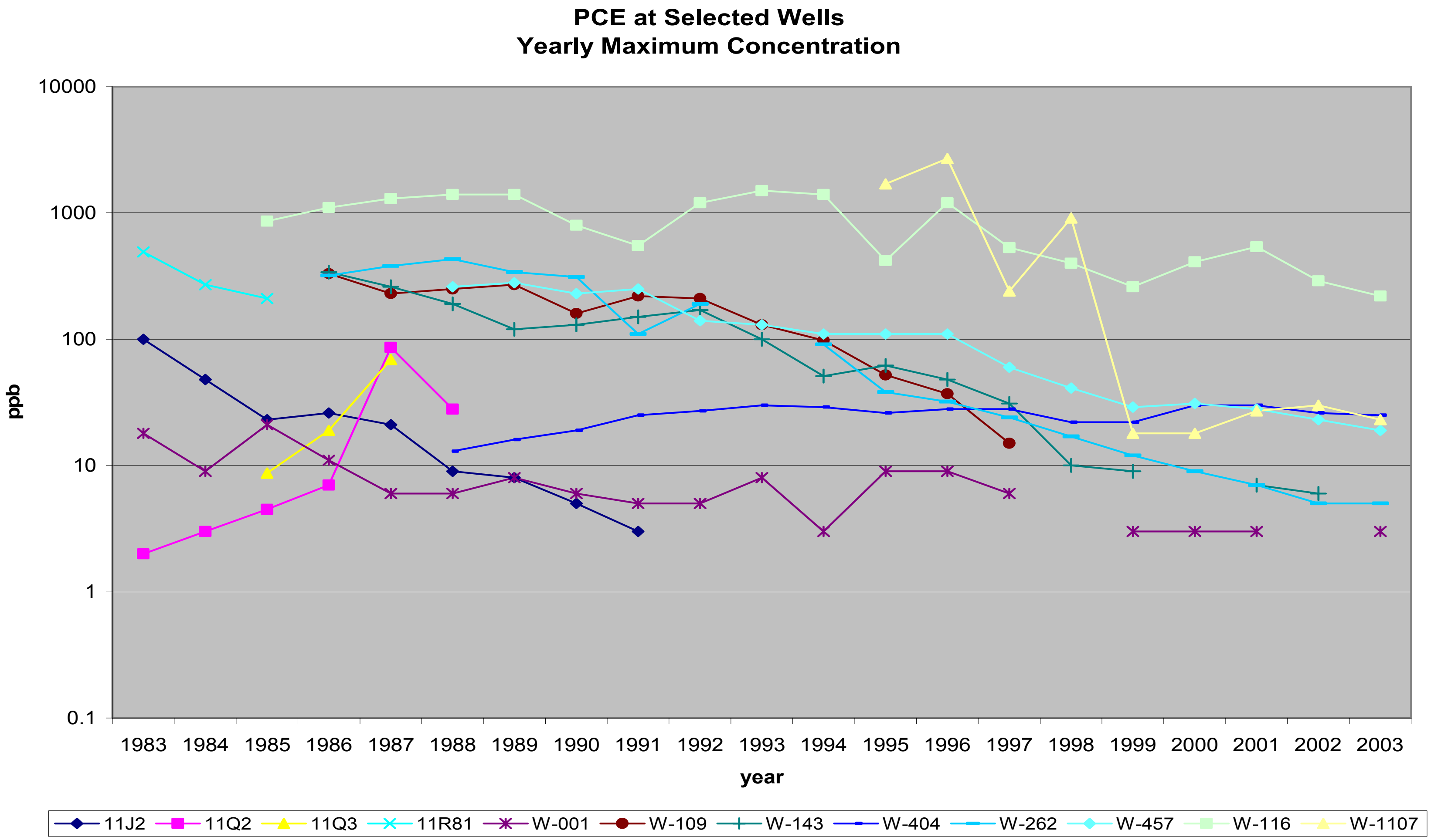


Figure A-2. Annual maximum PCE concentrations at selected ground water wells. Concentrations are declining over time due to ongoing remedial actions and dispersion. Well locations are shown in Figure A-1. Note that the concentration scale is logarithmic. Private off site wells that are sources of potential exposure have been destroyed (Table A-3).

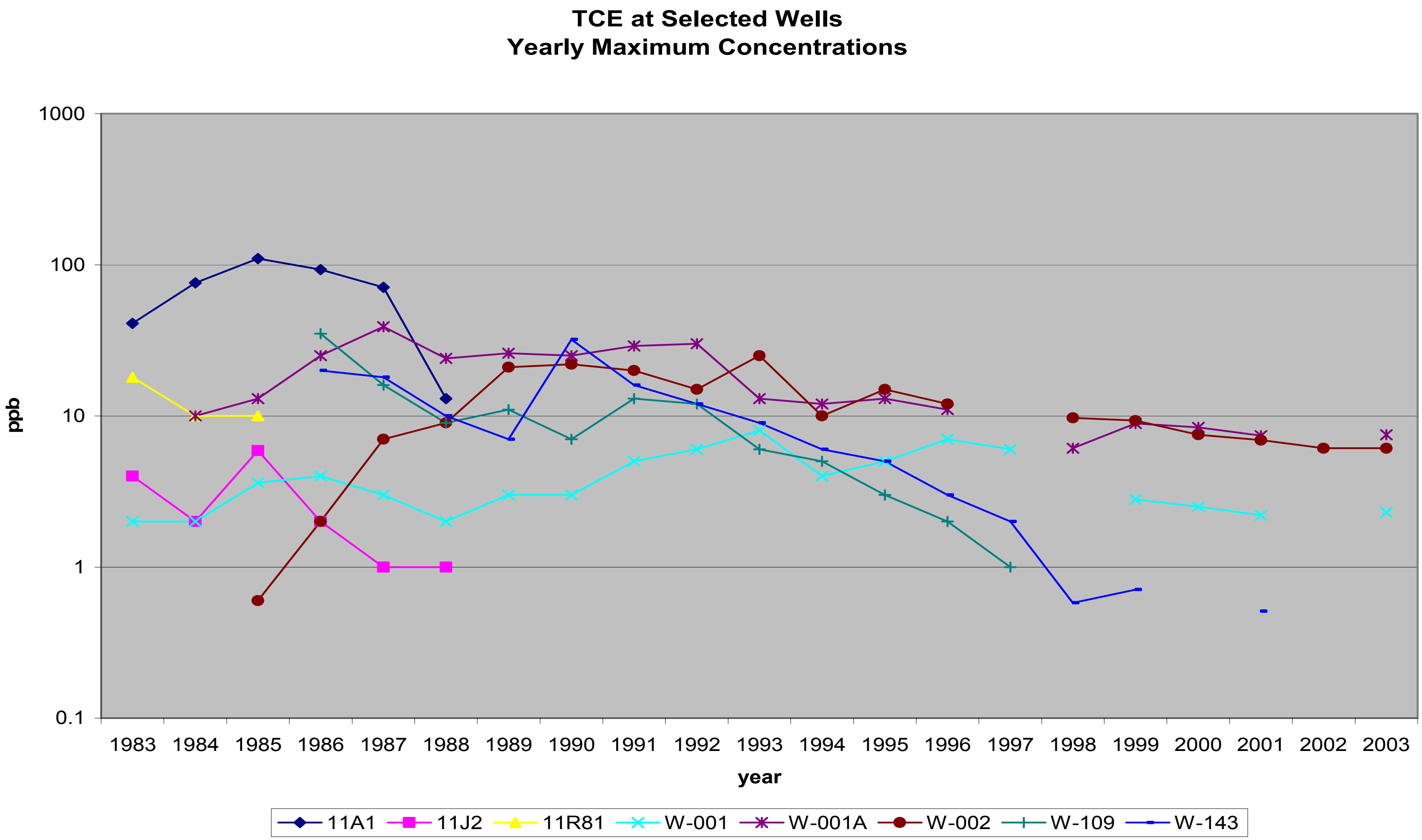


Figure A-3. Annual maximum TCE concentrations at selected ground water wells. Concentrations are declining over time due to ongoing remedial actions and dispersion. Well locations are shown in Figure A-1. Note that the concentration scale is logarithmic. Private off site wells that are sources of potential exposure have been destroyed (Table A-3).

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Table A-3. Private well inventory in the LLNL vicinity.

Well	Alias		(Zone 7)	Depth Zone7/LLNL (ft)	Perf. Int. (ft.)	Date Comp. Zone 7	Date Destroy. (Zone 7)	Date Comp. (LLNL)	Date Destroy. (LLNL)	Potential Current Exposure	Potential Past Exposure	Usage
Section 11 Zone 7 records id'd 17 private wells in Section 11. LLNL id'd 16 private wells as potential conduits for contam -- to date, LLNL destroyed 11 of 16 wells:												
11A1		(included in LLNL comments)		NA/65	54.7-59.7	NR	NR	6/8/1976	8/18/1988	N	Y	unknown
11A5				NA	NA	NA	NA	NA	7/19/1988			unknown
11BA		(included in LLNL comments)		NR	NA	NR	NR	3/2/1987	6/10/1987	N	Y	unknown
11C1				68								
11H1				519/481	157-479	11/16/1941	10/31/1988	11/4/1941	10/31/1988	N	Y	domestic
11H16				NA	NA	NA	NA	NA	NA	?	?	unknown
11H4	11H80			272	166-265	4/5/1960	10/7/1988	4/5/1960	10/7/1988	N	Y	domestic
11J1			8/3/1988	approx. 160	NA	4/24/1905	NA	1941	8/3/1988	N	Y	dom, not drinking
11J2				112								unknown
11J4	11J81			NA/12	NA	NR	NR	1965	10/11/1988	N	Y	unknown
11K1			9/26/1988	621/604	247-602	1/3/1942	NA	1/6/1942	9/26/1988	N	N	inactive
11K2			10/3/1988	NA/232	NA	NA	NA	6/17/1988	10/3/1988	N	N	inactive
11M1			10/13/1977	436/436	NA	7/7/1951	10/13/1977	NA	NA	N	Y	domestic
11P1	11P80		2/20/1975	NA/approx. 200	15-115	NA	2/20/1975	NA	NA	N	Y	domestic
11P2	11P81		2/20/1975	NA/22	None	NA	2/20/1975	NA	NA	N	Y	domestic
11Q2			8/16/1988	NA/264	NA	NA	NA	12/20/1983	8/16/1988	N	Y	dom, not drinking
11Q3			8/10/1988	<20/approx. 120	NA	NA	NA	12/20/1983	8/10/1988	N	N	inactive
11Q4			Jul-86	NA	NA	NA	Jul-86	NA	NA	N	Y	domestic
11Q5			Jul-86	NA	NA	NA	Jul-86	NA	NA	N	Y	domestic
11Q6	11Q81		10/3/1988	NA/approx. 280	NA	Feb-80	10/3/1990	12/20/1983	1/11/1989	N	Y	dom, not drinking
11R3	11R2		9/3/1985	117/approx. 140	33-138	5/8/1961	9/3/1985	5/8/1961	9/3/1985	N	Y	domestic
11R4	11R80		9/3/1985	268/268	165-258	Oct-58	9/3/1985	3/13/1984	9/3/1985	N	Y	domestic
11R5	11R81		7/26/1985	NA/336	125-325	Mar-66	7/26/1985	NA	7/26/1985	N	Y	domestic

Well	Alias		(Zone 7)	Depth Zone7/LLNL (ft)	Perf. Int. (ft.)	Date Comp. Zone 7	Date Destroy. (Zone 7)	Date Comp. (LLNL)	Date Destroy. (LLNL)	Potential Current Exposure	Potential Past Exposure	Usage
Section 14	Zone 7 id'd 29 private wells in Section 14.				4 of the 29 wells are no longer in use (source?):							
14A1	14A81			226/227(246?)	102-227	7/12/1943	9/13/1988	7/12/1943	9/13/1988	N	Y	domestic
14A11	14A84			NA	NA			NA	NA			
14A2	14A82			229	122-180	11/15/1956	9/12/1988	11/15/1956	9/12/1988	N	Y	domestic
14A3				110	100-105	12/7/1977						
14A4	14A83			252/252	167-246	7/15/1959	NA	6/15/1959	8/29/1988	N	Y	domestic
14A5				NA	NA	NA	NA	NA	NA	N	N	no pump
14A8				NA/86	NA	NA	7/22/1988	5/3/1988	7/22/1988	N	Y	domestic
14B1				300/300	146-234	8/13/1959	NA	8/13/1959	NA	N	N	inactive, no pump
14B2				312	185-312	8/22/1962	11/11/1988	8/22/1956	11/11/1988	N	Y	domestic
14B4	14B81			260/0	NA	Aug-60	NA	8/1/1960	NA	Y	Y	domestic
14B5			1981	NA	NA	NA	NA	NA	NA	N	?	abandoned
14B6				NA	NA	NA	NA	NA	NA	Y	Y	domestic
14B7			12/8/1980	NA	NA	NA	12/8/1980	8/25/1987	NA	N	Y	domestic
14B8				385	NA	NA	1989	5/3/1988	10/23/1989	N	Y	domestic
14C1												
14C2				NA	NA	NA	NA	1/7/1988	NA	Y	Y	domestic
14C3	14C2??			217/NA	NA	4/6/1968	NA	1/19/1988	NA	Y	Y	
14H1				NA	NA	NA	NA	12/21/1983	NA	Y	Y	domestic
14H2	14A6			NA	NA	NA	NA	8/28/1987	NA	Y	Y	unknown
14J1	P7879			176/NA	NA	6/16/1978	NA	NA	NA	Y	Y	domestic
14J3	P7893			NA	NA	NA	NA	NA	NA	Y	Y	domestic
14J4				260/NA	NA	8/3/1994	NA	NA	NA	Y	Y	domestic
14K1				372/NA	NA	7/7/1959	NA	NA	NA	N	?	domestic
14P2	14P1 ??			200/NA	NA	12/24/1978	NA	NA	NA	Y	Y	domestic
14Q3				308/NA	NA	Apr-54	NA	NA	NA	Y	Y	domestic
14Q4				294/NA	NA	7/19/1960	NA	NA	NA	Y	Y	domestic
14Q5				195/NA	NA	10/24/1983	NA	NA	NA	Y	Y	unknown

Well	**Alias**		**(Zone 7)**	**Depth Zone7/LLNL (ft)**	**Perf. Int. (ft.)**	**Date Comp. Zone 7**	**Date Destroy. (Zone 7)**	**Date Comp. (LLNL)**	**Date Destroy. (LLNL)**	**Potential Current Exposure**	**Potential Past Exposure**	**Usage**
Section 14	Zone 7 id'd 29 private wells in Section 14.				4 of the 29 wells are no longer in use (source?):							
14Q6				140/NA	NA	NA	NA	NA	NA	Y	Y	domestic
14Q7	P99A-1500-15			210/NA	NA	3/26/1987	NA	NA	NA	Y	Y	domestic
14R1	P77422			148	NA	May-77	NA	NA	NA	Y	Y	domestic
14R2				175	NA	7/23/1977	NA	NA	NA			
Section 1	Several private wells in Section 1 (id'd from ??) could be contam.											
1A1				NA	NA	NA	NA	NA	NA	?	Y	domestic
1D1												
1F1				113/NA	NA	NA	NA	NA	NA	N	Y	abandoned
1G1				NA	NA	8/18/1959	NA	NA	NA	?	Y	domestic
1G2				NA	NA	NA	11/10/1989	NA	NA	N	Y	unknown
1H1				NA	NA	NA	NA	NA	NA	N	Y	abandoned (86?)
1J1				124/NA	NA	NA	NA	NA	NA	?	Y	domestic
1J3				NA	NA	6/4/1979	NA	NA	NA	?	Y	domestic
1K1				200/NA	NA	2/21/1978	NA	NA	NA	?	Y	domestic
1N1				600	NA	1/15/1948	NA	1/15/1948	10/21/1988	N	Y	
1P2				144/NA	NA	Oct-60	5/22/1986	NA	NA	N	Y	unknown
Section 2												
2K3										N	N	
2K4										N	N	
2N1				NA	NA	NA	NA	NA	NA	Y	Y	unknown
2Q2										N	N	
2R3										N	N	
2R4										N	N	
2R8										N	N	

2R9	**11A5/W-409**			NA	NA	NA	7/19/1988	NA	7/19/1988	N	Y	Unknown
Well	**Alias**		**(Zone 7)**	**Depth Zone7/LLNL (ft)**	**Perf. Int. (ft.)**	**Date Comp. Zone 7**	**Date Destroy. (Zone 7)**	**Date Comp. (LLNL)**	**Date Destroy. (LLNL)**	**Potential Current Exposure**	**Potential Past Exposure**	**Usage**
Section 13												
Well	**Alias**		**(Zone 7)**	**Depth Zone7/LLNL (ft)**	**Perf. Int. (ft.)**	**Date Comp. Zone 7**	**Date Destroy. (Zone 7)**	**Date Comp. (LLNL)**	**Date Destroy. (LLNL)**	**Potential Current Exposure**	**Potential Past Exposure**	**Usage**
13D1	13D81			400	200-400	10/29/1956	8/23/1988	10/29/1956	8/23/1988	N	Y	domestic
13M1				200/NA	NA	3/10/1977	NA	NA	NA	Y	Y	domestic
13P2				100/NA	NA	Apr-77	NA	NA	NA	Y	Y	domestic
13P3				112/NA	NA	May-77	NA	NA	NA	Y	Y	domestic
13R1				80?/NA	NA	NA	NA	NA	NA	Y	Y	domestic
Section 12, On site Wells?												
12M1		(on site? included in LLNL comments)		NA/681(702?)	375-657	NR	NR	4/14/1942	1/24/1989	N	?	
12N1		(on site? included in LLNL comments)		NA/702	392-681	NR	NR	12/9/1942	4/15/1984	N	?	

Appendix 6: Peer Review and Other Comments and Responses to Public Comment Release

ATSDR has received six sets of comments from various reviewers or sets of reviewers, including three independent peer reviewers. This appendix includes all of the comments that are specific to this public health assessment document along with the ATSDR responses to those comments. The comments have resulted in a number of minor revisions to the public health assessment and have improved the technical accuracy and readability of this document. The ATSDR responses specify how the document was revised relative to each comment or indicate why no change was made.

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Peer Review Comments and ATSDR Responses

1. The section titled “Environmental Contamination and Exposure Assessment” contains the information regarding potential pathways of exposure. Although the section is very well written, it is difficult to find the exposure pathways, for example, for ground water. Table 4 and page 25 indicate that ingestion, dermal contact and inhalation are assessed, but it would be easier for the reader if a clear statement or a table were provided that summarized the exposure media and pathways, and whether these pathways/media combination was “complete.”

   Similarly, on page 36, “Soil and Sediment Exposure Pathways” should provide detailed information regarding the exposure pathways (ingestion, dermal or inhalation). The section only mentions that pathways are complete, but does not specify what pathway/population was considered. Are children playing in soils the primary consideration? Is gardening a pathway that is assessed?

   In contrast, the explanation provided on page 44 (Surface Water Exposure Pathways) provides a somewhat more coherent description of possible pathways, and which ones are incomplete. It would be helpful if a single table was provided outlining pathways by media, including comments on why the pathway is complete or incomplete.

ATSDR Response: All of the information related to completed or potentially completed pathways of exposure including the media, relevant contaminants of concern, the exposure routes, the exposed population, and the status of each pathway are summarized at the beginning of the Public Health Implications section and in Table 11. Areas of exposure for each pathway are also shown on a site map in Figure 3. Appendix 5 contains all of the information related to estimation of the contaminant doses for the ground water pathway.

There are no completed pathways of exposure for soil/sediment for non-radiologic contaminants. This statement has been added to page 36. Potential exposures to radiologic contaminants (principally tritium and Pu 239) have been thoroughly evaluated in previous (referenced) PHAs. Table 11 and Appendices 2 and 3 summarize the information underlying those evaluations and specifically identify children and consumption of food from home gardens as the exposed populations.

2. For ground water, how is the determination made that sampling 6 or fewer wells provides a complete picture of ground water contamination? This seems like too few wells to eliminate contaminants of concern in this assessment, and may not be a very conservative approach. Generally, in Human Health Risk Assessment, a single detection can be used to capture as contaminant for assessment.

   The use of a 95% percentile is appropriate for determination of exposure dose. Details of the calculations are not provided (for example, averaging time and exposure duration). This information is needed to determine if appropriate estimations have been made.

A single table that outlines exposure assumptions would be useful. Although many of the assumptions can be found in several tables (for example, Table 10 provides the assumptions that incidental ingestion of water = 0.5 L/week), a clear presentation of the assumptions would make this report much better.

ATSDR Response: This assessment of ground water contamination at the LLNL site includes evaluation of more than 566,000 analytical records from more than 550 monitor and private wells (this statement has been added to the ground water section). The six wells that are specifically referenced are the only off site private wells where any contamination has been detected. Table 4 lists the explicit exposure factors used in estimating doses from ground water with additional details on the temporal and spatial distribution of the ground water contaminants provided in Appendix 5.

3. The PHA discussed the potential acute and chronic health effects of the contaminants of concerns, and provides a concluding remark as to whether or not acute and chronic effects are of concern to potentially exposed populations. The discussion could be presented more clearly, perhaps by separating the discussion of chemical specific effects from the discussion of results in the "Public Health Implications" section.

ATSDR Response: The "Public Health Implications" section summarizes the exposure pathways, then addresses the potential for cumulative exposure across pathways, and then presents the potential health effects from each of the "contaminants of concern" in separate subsections. Concluding remarks are presented in the "Conclusions" section.

4. The PHA accurately communicates the health hazards posed. The clarity of this communication could be improved substantially through the use of additional tables, brief section summaries, and separation of technical discussions. Specifically, rather than present the hazard discussions in the same section with the assessment results, it would be helpful to present the hazards in a separate section.

ATSDR Response: No comment is necessary.

5. An executive summary, written for the non-technical reader, would be very useful.

ATSDR Response: This PHA has been reviewed and edited by ATSDR writer/editors for technical clarity and the use of appropriate, non-technical language. The existing summary adequately conveys the PHA evaluation and findings for the Livermore community.

6. Pathways are generally well identified. As a minor comment, note that, Figure 2, which appears on page 12 of the report and is the generic illustration shows as the source of contamination a "Nuclear Plant". Rather than the semi-generic term "Nuclear Plant", it might be preferable to identify the contamination source with the term "Contamination

Source" or specifically as "LLNL".

ATSDR Response: As stated, this is a generic illustration of the pathway evaluation process and is not specific to LLNL.

7. It would seem appropriate to include beryllium in Table 3 and Pu-239,240 and Am- 241 in Table 4. By so doing, the point that they are not contaminants of concern would be better made.

ATSDR Response: Beryllium and plutonium (238 and 239/240) have been added to Table 3. As the above radionuclides are not preliminary contaminants of concern, it would be inappropriate to include them in Table 4.

8. The section "Public Health Implications" is particularly well done, and the discussion with respect to tetrachloroethylene (CE) is outstanding.

ATSDR Response: Thank you.

9. A number of minor items, largely of an editorial nature, have been identified in the form of comments and suggestions on the draft. These include such things as the suggestion to label the abscissae of the exposure dose figures in the text, identification of minor grammatical errors, and similar comments. It should be stressed that none of these comments imply in any way that the conclusions of the public health assessment are flawed or not fully supported by the data and analysis.

ATSDR Response: The editorial comments and suggestions have been reviewed and amended as appropriate. (Note, the abscissae on the dose figures are appropriately labeled as mg/kg/day.)

10. The omission of consideration of Am-241, which is invariably associated with Pu from this document is puzzling. Given the level of Pu it is unlikely that Am would be of public health significance, but if for no other reason than completeness, it would be well to include some statement(s) re Am-241. Similarly, the discussion of Be could be expanded, particularly in the early parts of the report.

    All in all, however, this is a well done Public Health Assessment. It appears to be a largely complete and thoughtfully prepared analysis, and is well written and easily read.

    Finally, regarding the specification of Pu-239: Unless very specialized and expensive analytical techniques are used, Pu-239 is virtually impossible to separate from the 240 isotope, which is usually present albeit in small amounts relative to the amount of the 239 isotope. Hence when analytical results are reported in terms of Pu-239, they are likely to include both the 239 and 240 isotopes. From a health standpoint, this is of little consequence as the decay characteristics and hence radiotoxicity of the 239 and 240 isotopes are similar. Given the above, it would be more precise and appropriate to report Pu-239 as Pu 239,240. Doing so would also provide a measure of consistency and alleviate the potential for questions on the part of the reader as to why some data and measurements are in terms of Pu 239 while others are in terms both isotopes.

ATSDR Response: Americium 241, a decay product of plutonium 241, is not a contaminant of concern for this site. Nonetheless, the potential dose contributions from Am 241 and the various plutonium isotopes have been explicitly estimated in a previous PHA (ATSDR 2003d). As suggested, those dose contributions are relatively minor and do not change the health conclusions. In fact, the individual EPA and ICRP dose coefficients for Pu 239 and Pu 240 in adults are identical. As you indicate, because many of the plutonium analyses do not effectively discriminate between individual isotopes, plutonium doses were estimated using typical isotopic ratios of weapons-grade plutonium. Explanatory footnotes from the previous PHA (2003d) have been added to this document.

11. More basic information on past history needs to be included. It was disappointing that documents in the peer review literature were not quoted in this document as background to its environmental pollution potential. One such example is the 1982 paper of Timourian et al, Mutagenic and toxic activity of environmental effluents from underground coal gasification experiments, *J Toxicol Environ Health* 9: 975-994, 1982. This paper indicates that mutagens were present in groundwater with preliminary identification of these as quinoline and aniline derivatives as well as toxins like phenolic compounds. Tar compounds from product gas were postulated to be the major source of mutagenic compounds in the air and groundwater. This paper needs to be discussed and any contrary evidence introduced. These "old" concerns need to be addressed to reassure the public. This matter was not addressed in Appendices 2 and 3 or in the main text.

ATSDR Response: As stated in the Introduction, this PHA "addresses potential off site (community) exposures to radioactive and non-radioactive substances released from the main site of the Lawrence Livermore National Laboratory (LLNL)." The above cited example (Timourian et al. 1982) refers to a coal gasification experiment conducted at Hoe Creek, Wyoming and is not related to the LLNL main site. Further, the EPA has completed a site evaluation of the Wyoming site and found that no further remedial action is warranted (http://web.em.doe.gov/cercla97/hoe.html).

12. Another more recent publication (Campbell et al: Investigating sources of toxicity in stormwater: algae mortality in runoff upstream of the Lawrence Livermore National Laboratory (*Environmental Practice* 6(1):23-25, 2004) should be included to update the introduction re effects of applied herbicides.

ATSDR Response: The above cited publication quantified sources of herbicides in storm water flowing onto the LLNL facility from upstream locations and as such are not related to the LLNL site, but emanate from upstream agricultural activities. Extensive monitoring of LLNL storm water effluent has not detected similar herbicides at levels of public health

concern, except as noted in the PHA.

13. Some relevant California Department of Health Services reports that are not referenced and discussed (<u>AND MUST BE</u>) include:

    1. CDHS. Cancer incidence among children and young adults in Livermore, California: 1960-1991, Sep 6 1995.
    This study found an excess of melanoma in young community residents (2.4 times higher than expected for children and 6.4 times for <24 yr adults born in Livermore), but no excess leukemia and non-Hodgkin's lymphoma incidence. The excess melanoma was greatest before 1970 to mid 1980s. Excess brain cancer in children and young adults <24 yrs was found in 1960-69, the incidence decreasing after 1969.

    2. California Cancer Registry (CDHS). Cancer Incidence in California: 1988-1993, Sacramento CA, 1996.
    This study found that the Livermore community melanoma incidence was not elevated relative to the San Francisco Bay area in 1988-1993. While the melanoma incidence in the 4515 census tract next to Livermore was elevated, the authors thought this might be random happenstance. The numbers involved were small.

    3. JA Harris (California Birth Defects Monitoring Program (CDHS). Birth Defects around Livermore: 1983-1989, March 15 1996.
    This study found that the overall rate of Livermore birth defects (2.5/100) in 1983-1989 was similar to the statewide average (2.9/100).

ATSDR Response: The above cited health studies have been individually cited and reviewed in a referenced Public Health Consultation on "Review of Health Studies Relevant to Lawrence Livermore National Laboratory and the Surrounding Community." The conclusions and recommendations of the public health consultation are summarized in the section on community health concerns. As the potential community exposures estimated in this PHA are significantly below any doses likely to produce any adverse health effects, more detailed evaluation of those background health studies is unnecessary.

14. I have a concern that data on lung damage caused by exposure to air radionuclides, methemoglobinemia caused by exposure to surface/ground water, food, and air nitrate, nitrite, aromatic amines (see Section 1), and organic nitro compounds, and radon air data have also not been presented. I would like to see these endpoints discussed as to why they were not included. In addition, some human monitoring data on the people who have been exposed the longest and live the nearest would have been nice to prove that the models are correct.

    Radon exposure can also increase melanoma incidence in home exposures (DL Henshaw, JP Eatough, RB Richardson. Radon as a causative agent in induction of myeloid leukemia and other cancers. The Lancet 335: 1008-1012,1990; O Axelson. Cancer risks from exposure to radon in homes. Env Hlth Perspect 103 (Suppl 2:37-43, 1995; DJ Etherington, DFH Pheby, FI Bray. An ecological study of cancer incidence and radon levels in south west England. Eur J Cancer 32A: 1189-1197, 1996; JF Winther, K Ulbak, L Dreyer, E Pukkala, A Osterlind. Avoidable cancers in the Nordic countries. Radiation. APMIS Suppl. 76: 83-99, 1997).

Lung deposition of actinide radionuclides could be assessed by computed lung tomography scanning data (D Franck, FD Borissov, L de Carlan, N Pierrat, JL Genicot, G Etherington. Application of Monte Carlo calculations to calibration of anthromorphic phantoms used for activity assessment of actinides in lungs. Radiat Prot Dosimetry 105: 403-408, 2003.)

ATSDR Response: There are no significant emissions of radon from the LLNL main site. Although radon has been detected in ground water monitoring wells, the concentrations are within the range of normal background values for this area and most likely occur as a result of the decay of naturally-occurring uranium deposits. With regard to radionuclides in air, the MRL is based on the health protective endpoints and explicitly includes any types of cancers, including lung cancer, as a potential health effect [ATSDR 1999c; Minimal Risk Level (MRL) Worksheet]. As the estimated radiological doses are much lower than the doses that produce any adverse health effects, there is no need to discuss organ specific health effects. Methemoglobinemia, as related to nitrate ingestion is specifically mentioned in the Nitrate portion of the Public Health Implications section.

15. The phrase "of public health concern" is very vague and should be defined as part of the Introduction. If it means "exceeds no existing public health guidelines" why not say that? The public can show a "concern" whether there is a real danger or not. The public will always be "concerned" about radiation risks, in my view.

ATSDR Response: The term "contaminant of concern" is defined in the introductory section of Environmental Contamination and Exposure Assessment and in Appendix 1 as "(1) whether environmental levels exceed media-specific comparison values, (2) noted community health concerns, and (3) the quality and extent of sampling data with which to evaluate potential exposure and human health hazard." This term has been revised to "contaminant of (public health) concern."

16. There are no actual human biological monitoring values quoted to compare. The PHA fails in this regard. There are many environmental exposure media data however. While models might predict nondetectable concentrations in humans, some real human sampling in the most exposed community persons (that is, those living closest to LLNL and for the longest time) should be done to reassure the public.

    Another issue is whether there is a threshold for biological effects for radionuclides or carcinogens. This issue should be stated frankly, since keeping exposures to the lowest technologically possible is the outcome of a non-threshold exposure model. While the animal carcinogen PCE is probably correctly not perceived to be a human carcinogen, this is not so for radionuclides where a tumor incidence of 10^{-6} is usually considered minimal risk.

ATSDR Response: Based on the health protective estimates of community doses from LLNL-related contaminants in this PHA, there is no public health basis for the collection and analysis of human biological samples. ATSDR only recommends human sampling if exposure assessments indicate the potential for doses that may lead to adverse health effects.

17. Specific Comments:

1. P2 para 3: The potential for contaminated workers to contaminate their homes and family should be addressed. Are there any known instances of this in LLNL workers?

ATSDR Response: The LLNL Environmental Safety and Health Manual includes both general and substance-specific procedures regarding the use and disposal of personal protective equipment (including gloves, aprons, clothes, and respiratory protection) to prevent the accidental or incidental dispersion of hazardous substances. Adherence to these common-sense workplace regulations will prevent secondary contamination of worker residences and family exposures. LLNL's chief medical officer is unaware of any instances of such secondary contamination and has received no related comments or questions from LLNL employees (J. Seward, personal communication with M. Evans, 4/27/04).

2. P4 2nd last para: Define the public health concerns.

ATSDR Response: Potential public health concerns were not explicitly described in the referenced preliminary document. However, they are explicitly listed in Table 1 of this PHA.

3. P4 last para: What were the results of the evaluation and a reference?

ATSDR Response: The site scoping visit determined that there were no immediate public health hazards at the LLNL site and the specific issues identified in that evaluation have been addressed in this or previous PHAs or health consultations. As the site scoping visit produced no referable document, this bullet has been deleted from the PHA.

4. Table 1 should be after the current p6 since ATSDR 2003a is 1st mentioned at the bottom of the current p6. The statements in Table 1 should be oriented towards health effects on the surrounding community since that is the focus of the current document. Suggest a 3rd column entitled Community Impact.

ATSDR Response: The table has been moved as suggested. The conclusions of the public health actions are discussed in the text or in the referenced documents.

5. From Table 1, the rates of malignant melanoma should be provided in the text for the population surrounding LLNL. (Gong et al. Cutaneous melanoma at Lawrence Livermore National laboratory: comparison with rates in two San Francisco bay area counties. Cancer Causes Control 3(3): 191-197, 1992 and of course, more recent incidence data if available).

6. Table 1 (7): If there is an excess melanoma incidence in workers and the workplace is not responsible, the overexposure must come from nonwork-related exposure, the subject of this PHA. Delete the last sentence in the right hand column "As LLNL workers…contaminant exposures" since it is not logical. If there is no significant increase in Livermore workers, this needs to be stated with a reference. Is item (7) supposed to be a community oriented priority issue since it and item (2) are nearly identical?

7. p7 para 2 L8: Does this "behavioral response to sunlight" also apply for community? Give the reference for this statement.

8. p7 para 2 2nd last sent: Provide the reference for this statement.

ATSDR Response: There have been at least 17 studies or reviews of melanoma incidence rates in LLNL workers or the surrounding community. The health consultation that presents a comprehensive review of those studies is cited in this PHA, as are the general conclusions and recommendations of that health consultation. Listing of the specific melanoma incidence rates from all of these studies would be inappropriate for this PHA.

9. Table 2: There are some questions that need to be answered arising from this table.

a/ On p 16, was the Bldg 612 area paved or lined? 'Unknown" is not acceptable.
b/ On p16, Bldg 518: what is 1,1,1-TCA? It is not defined anywhere
c/ On p16, Bldg 298/Firetraining area: Have the VOCs from fire training been measured during drills? Do they impact the off site community? Are there PAH residues on pans and how are they cleaned? Do the waste residues go into the sewer?

ATSDR Response: Each of these potential source areas for ground water contamination has or is currently undergoing remediation. The reference to "uknown" status has been revised accordingly. The reference to 1,1,1-TCA has been deleted. The fire training area dates from the World War II-era naval air station and no longer exists (and is so noted in the table).

10. p17 2nd last para L3: "distributions"
11. p19 last para 2nd last L: radon with small "r"
12. p20 para 1 L1: "is" not "in"
13. p20 2nd last para L4, last para L2: "volatilization"
14. p20 last para L4; also p47 last para L4: "volatilize"
15. p22: Put the footnotes at the end of Table 3 on p24
16. p31 Table 6 last L: Dimethylsulfide

17. p32, p33 PCBs: “Aroclor” not Arochlor

ATSDR Response: The above editorial comments have been revised as appropriate.

18. p34 para 3 and last para: Shift to air section on p45ff: aerosol is not soil or sediment

ATSDR Response: These paragraphs refer to soil contamination that may be due to aerosol deposition and have been so clarified.

19. p40: Bromacil

ATSDR Response: Revised as suggested.

20. p45ff Air: Include the sections of #18. Why are there no radon (Rn) air data too (or was this part of the total air alpha data?) since these are linked to U, Th and Ra? Why isn’t there a summary Table like for Groundwater and Soil/Sediment?

ATSDR Response: LLNL has no significant emissions of radon and consequently does not specifically monitor this radionuclide in air. Radon 222 is part of the uranium decay chains and if the uranium is purified, the half lives of these radionuclides are so long, that there is no appreciable radon release. Radon 220, with a half life of 57 seconds is produced by thorium. However, as an alpha-decay radionuclide, radon emissions can be captured in gross alpha air monitoring analyses, depending on the sampling and analysis method.

21. p47 2nd last para L4: delete the 2nd “the”
22. p52 (not numbered) Table 11: Surface Water/Air sections: “absorption”; Why are there no radon air data?
23. p54 last para L3: “substances” is incorrect: you mean “atoms”

ATSDR Response: The above editorial comments have been addressed as appropriate. See above response concerning radon air monitoring.

24. p55 para 2 L4: There is a disconnect here between the effects of elemental boron and borates. Borates are meant since atomic boron is too reactive to exist by itself in the environment. This paragraph should refer to the essentiality of boron to plants and fish.

ATSDR Response: The references to “boron” have been revised to borates or boron compounds.

25. p57 para 2: Insert after the last sent: “Exposure to xenobiotics like aromatic amines and nitro compounds may also cause methemoglobinemia. Timourian et al (1982) detected quinolines and aromatic amines in environmental effluents from LLNL underground coal gasification experiments.” Is there any more information on this?

ATSDR Response: There are no significant releases or measured concentrations of amines or nitro compounds from the LLNL main site. See the response to comment 11 regarding the Timourian et al. reference.

26. p57 para 3 last sent L4: insert "or salads preserved with nitrite" after the last "nitrite"

ATSDR Response: Revised as suggested.

27. p60 2nd last para: the definition of dose is not the usual toxicological definition which usually means "absorbed dose" rather than "exposure dose". The ATSDR definition means "exposure dose"

ATSDR Response: This is the definition used by ATSDR and is so defined in Appendix 1.

28. p61 last para after last sent: Add "Most absorbed PCE is breathed out".

ATSDR Response: The preceding sentence already states that "Most absorbed PCE is eliminated unchanged via the lung…"

29. p62 para 1 L1: specify the gender of the mice and rats
30. p62 para 1 2nd last L: "were" not "was"
31. p62 last para 3rd last L: Glutathione-PCE conjugate formation does occur in humans so delete this.
32. p63 2nd last para: Update reference to ACGIH 2003 since it is still true.
33. p64 para 1 L5: Insert after "effects" the following "of irritation at the point of contact and central nervous system effects".

ATSDR Response: The above editorial comments have been revised as appropriate.

34. p65 last para: This is very misleading: Jonker et al investigated 4 nephrotoxins that should be identified, and Groten et al studied 8 metals (Ca, P, Mg, Mn, Cu, Fe, Zn, and Se) for their interaction on Cd. These studies are very limited so that the statement "The absence of interactions at doses 10-fold or more below effect thresholds… Groten et al (1991)" should be qualified by stating the specific chemicals involved.

ATSDR Response: ATSDR has reviewed the scientific literature surrounding chemical interactions and noted that if the estimated exposure doses for individual contaminants detected at the site are below doses shown to cause adverse effects (No Observed Adverse Effect Level; NOAEL), then ATSDR considers that the combined effect of multiple chemicals is not expected to result in adverse health effects. We believe that the statement "The absence of interactions at doses 10-fold or more below effect thresholds have been demonstrated by Jonker et al. (1990) and Groten et al. (1991)" is in it's entirety not

misleading and appropriately states that "The absence of interactions … was demonstrated" in those two studies.

35. p66 para 1: Indicate the types of 40 carcinigens investigated by Takayama et al (1989). Were any heterocyclic amines as studied by Hasegawa et al (1994)? If not, delete the "However". You must be specific here and not generalize.

ATSDR Response: ATSDR agrees that "However" can be deleted but will replace it with "Additionally".

36. p66 footnote: I question the assertion that "the dose from any form of tritium taken into the body remains constant year after year following an intake." This is certainly not true for tritium gas since most will be expired on being breathed in and very little exposure will occur systemically although the lungs will be affected. What modeling was done? Summing the dose from ^{3}H and Pu is NOT acceptable since tritium is only a weak beta emitter and Pu is an alpha and X-ray emitter. These isotopes have different biological effects that are not additive unless the lung is the target organ.

ATSDR Response: This sentence has been revised to read "the dose from any form of tritium absorbed into the body…" The summed radiological doses are whole body committed effective dose equivalents which include weighting factors to account for the biological effects of the different types of decay. The addition of these doses, therefore, is radionuclide independent.

37. p68 2nd last para after "nitrate-contaminated water": Add "The incidence of methemoglobimimia should be monitored".

ATSDR Response: We have recommended additional evaluation of the potential distribution and exposures to nitrate in area ground water by the responsible local and state health agencies. Due to the stated limitations of the LLNL site specific monitoring data for evaluating this type of area-wide contamination, we are not sure that there is any significant exposure to nitrate. The specific process or procedures by which this problem is addressed by the local and state health agencies should be determined by those agencies and not dictated by ATSDR.

38. p70 ATSDR 2003b: The month of publication was September 30 NOT October

ATSDR Response: Revised as indicated.

39. p90 2nd last para 3rd last sent: Exposure to tritium gas may cause lung damage and this should be stated after this sentence.
40. p90 last para L2: "very little radiologic dose" to what? There may be a large dose to the lungs but certainly not to the liver.
41. p91 2nd last para sent 1: Is this true for lung tissue?

42. p91 last para 1 sent 1: the effects of tritium cannot be compared with low energy gamma or X rays since tritium is a beta emitter; delete the parenthetical material.

ATSDR Response: The above comments refer to verbatim summaries from previous PHAs and cannot be changed in this document. However, responses to the above comments are in order:

39. Inhalation of tritium as either HT gas or water vapor (HTO) does not result in a concentrated lung dose. The tritium is rapidly incorporated into the body as water and uniformly distributed throughout the entire body (any absorbed HT is rapidly converted into HTO).
40. This sentence correctly states that there is very little radiological dose from direct inhalation of tritium as HT or TT because very little of the hydrogen gas is absorbed into the body (the HT dose is about 1/10,000 of the dose from exposure to the same concentration of HTO).
41. See 39, above.
42. No adverse health effects have been documented from exposure to tritium. Consequently, risk factors for tritium exposure have been extrapolated from a-bomb survivors (external gamma exposure) or studies of x-ray exposures (see ATSDR 2002 for an extensive review of tritium dosimetry and risk assessment).

43. p95 para 1 after last sent: Insert " Health effects are usually divided into contact (portal of entry and related to exposure dose) effects or systemic (related to absorbed dose)." This statement is important because portal of entry effects have been largely ignored in the PHA.

ATSDR Response: Ultimately, only an absorbed dose has a biological effect. The dose may be taken in through direct contact (through skin or open wounds) or via ingestion or inhalation. The primary media that requires an evaluation of direct contact is contaminated soil or sediment for which there are no completed pathways for non-radiological contaminants. Radiological doses include both a dermal contact component and direct external irradiation component (these dose evaluations are more completely described in previous documents; ATSDR 2003c; 2003d). Other potential dose estimates (such as VOCs) also include a direct contact component as identified in Table 11.

44. The abbreviations page (page v) is incomplete: The following need to be defined: 111-TCA; 1,1-DCE; PCBs; Pu; CDHS; CV; SNL-L; RMEGc; RMEGcc; HGs;DCA; Th; Cs; Am; SL; K; ICRP; mrem; U; Ra; Cu; MOE; MCLGs;

45. List of abbreviations: p (pico) is 1 x 10^{-12} NOT 1 X 10^{-15}

ATSDR Response: The above items have been revised as suggested.

46. I recommend adding air monitoring for radon allied with lung damage and actinide

lung deposition indices, and biological monitoring for methemoglobinemia (healthy effect for nitrate/nitrite, aromatic amine, nitro compounds exposures) in humans in addition to the ongoing melanoma monitoring in the community.

ATSDR Response: See above responses to comments 20, 37, and 11, respectively.

Other Comments and ATSDR Responses

18. Incorrect PCE ground water value used in dose calculation leading to unsupported conclusion. (Health hazard category/conclusion incorrect for ground water pathway.)

ATSDR Response: As indicated in this comment, the Ground Water section and Appendix 5 include inconsistent statements regarding the 95th percentile PCE concentrations. The 95th percentile concentration (209 ppb) as presented in the Ground Water section (and subsequent dose estimates; Table 4) is based on the values of annual maxima of measured PCE concentrations in six off site residential wells. The 95th percentile concentration of 1,262 ppb, as presented in Appendix 5, is based on the measured concentrations of all private and monitor wells from the southwest PCE plume (on site and off site).

We have re-evaluated the PCE exposure factors and the PCE measurements in all wells with particular emphasis on those off site residential wells with documented exposure in order to define the most appropriate PCE concentrations and exposure factors to use in estimating past doses. For several reasons, neither of the above dose ranges cited above are appropriate for dose calculations. As your comment indicates, the 95th percentile value of 209 ppb does not adequately capture the highest measured value in one residential well (11R5). Conversely, the 95th percentile value of 1,262 ppb is based on high PCE concentrations in depth-restricted monitor wells. Wells W-116 and W-1107 are screened from 86 -- 91 feet and 74 -- 88 feet, respectively and are located at on site source areas. Consequently PCE concentrations in these wells are considerably higher than the measured concentrations from any residential location (well 11R5 is screened from 125 to 325 feet) and cannot be used to extrapolate past exposure concentrations.

One residential well (11R5) had significantly higher PCE concentrations than the other residential wells. Seven measured PCE concentrations from 11R5 varied from 110 to 490 ppb. 11R5 samples analyzed from December 1983 varied from 310 to 490 ppb. Samples from March 1984 varied from 110 to 270 ppb and one sample from April 1985 measured 210 ppb (the well was destroyed in July 1985). To calculate the PCE exposures from this location, this re-evaluation of PCE concentrations uses all of the measured values from the 11R5 well as a normal probability distribution with a mean concentration of 241 ppb and a 95th percentile value of 511 ppb. (PCE concentrations for well 11R5 in Figure A-2 include only annual maxima.) Note that the 95th percentile value is greater than any of the measured concentrations in this well and is significantly larger than the measured values in

any other off site residential well (a table listing all of the off site residential well PCE measurements has been added to appendix 5).

The PCE dose estimates have been revised using the well 11R5-specific PCE concentrations. The 95th percentile dose from this re-evaluation is 0.03 mg/kg/day for an adult (although there were no children residing at this location, a child dose would have been 0.05 mg/kg/day). The 95th percentile adult dose is below the ATSDR acute MRL of 0.05 mg/kg/day. We have also used the measured PCE water concentrations to estimate the whole house PCE air concentration (using the Life Systems, Inc. whole house model) and found that the 95th percentile whole house PCE air concentration of 0.03 ppm is below the chronic MRL air concentration of 0.04 ppm. On the basis of these revised dose estimates, the PCE exposures are still below levels that are expected to cause adverse health effects. Consequently, this pathway, and the LLNL site in general are determined to be "No Apparent Public Health Hazard." All pertinent sections of the PHA have been revised accordingly.

19. Air pathway incomplete due to insufficient discussion and presentation of data. For example, various plating activities occurred (may still be occurring) at LLNL, which released contaminants to the air, such as hexavalent chromium (and others; p. 18). Another source of airborne hexavalent chromium was from the cooling towers. Inhalation of hexavalent chromium is a known human carcinogen. Air releases from both of these sources have the potential to impact the surrounding communities at substantial distances. If there is no sampling data for these contaminants, which is likely the case (especially pre-1990s), then it should be stated that potential air exposures from LLNL cannot be evaluated due to a lack of data; and appropriately concluding there is an indeterminate health hazard in past (current?) from air releases at LLNL.

ATSDR Response: As indicated in this comment and the PHA, LLNL operations and processes include a variety of air releases and emissions of numerous hazardous substances. These air emissions are regulated by Federal, State, and local agencies with periodic inspections. As stated, there is no ongoing air monitoring data for the vast majority of these releases. The reason these emissions are not specifically monitored is because the operations and releases involve minor amounts of hazardous substances and result in insignificant air emissions.

With regard to emissions from water cooling towers, no hexavalent chromium compounds have been used since approximately 1970 (letter from R.C. Ragaini, Dept. Head, Environmental Protection, LLNL to the Bay Area Air Quality Management District, San Francisco, CA, April 18, 1990). While some hexavalent chromium may have been emitted from the cooling towers before 1970, such emissions are dispersed very short distances before deposition (typically less than 1000 meters). Considering the potential magnitude of the emissions, the locations of the cooling towers, and the prevailing wind directions, there is very little potential for significant exposures to airborne hexavalent chromium to members of the surrounding community. Because these air releases present very little potential for significant off site exposures an "indeterminate health hazard" conclusion is

not appropriate.

20. Non-cancer health effects evaluation (increased cancer risk) was conducted. Conduct cancer health effects evaluation for all site-related contaminants of concern. (Use OEHHA cancer potency values.)

ATSDR Response: There are no completed pathways of exposure for the vast majority of LLNL-specific contaminants. Consequently, neither cancer nor non-cancer health effects evaluation is necessary. Of the seven preliminary non-radiological contaminants of concern for which there are completed or potential pathways of exposure, only chromium-6, PCE, and TCE are considered human carcinogens. Chromium-6 is only present as contaminant of concern for the ground water pathway (see above concerning potential air exposure) and is not a carcinogen for oral exposure (Group D carcinogen for oral exposure; EPA IRIS 2004). The carcinogenic classifications for both PCE and TCE have been withdrawn (EPA IRIS 2004). The rationale for not evaluating PCE (and by extension TCE) as a carcinogen is clearly explained in the Public Health Implications Section. Briefly, these substances are more toxic for their non-cancer effects than for any potential cancer effects.

21. Cumulative exposure to all site-related contaminants in all media is absent. Evaluate cumulative exposure to all contaminants of concern in all media, for non-cancer and cancer health effects.

ATSDR Response: As stated above, there are no completed pathways of exposure for most site-related contaminants and consequently no potential for cumulative exposures. For all contaminants of concern, the public health implications section explicitly lists and evaluates all of the potential cumulative exposures across media, and for the radionuclides sums potential doses for different nuclides (as summarized in Tables 11 and 12). Estimated doses to VOCs (PCE, TCE) explicitly include dose components for ingestion, inhalation, and dermal contact and thus represent cumulative dose estimates. The public health determinations are all based on evaluation of cumulative doses (pages 53-64).

22. **The following editorial comments have been addressed as appropriate.**

Page vii, 2nd complete paragraph, 2nd sentence

Minor clarification suggested: DOE rather than LLNL is the property purchaser and owner. Suggest replacing "which were purchased by LLNL" with "were purchased by DOE to serve as buffer zone for LLNL".

Page vii, last paragraph

It reads as if both the Pu and tritium releases occurred in 1965 and 1970. The tritium releases occurred in 1965 and 1970; the Pu releases occurred in 1964 and 1967.

Page 2, 2nd complete paragraph, last sentence

LLNL does provide the worker training and monitoring for potential worker exposures suggested via LLNL's safety department ("Hazards Control Department").

Page 6, last bulleted item

Suggest you clarify "(main and 300 sites)" so that readers will not presume 301 LLNL sites. It could be rephrased as "(Livermore Site and Site 300)".

Page 7, second bullet, line 8

This states that potential dose is underestimated by a factor of 1.2 to 1.3 if OBT is neglected. However, on page 27 of the July 2001 final report of the expert panel, it states "…the dose from OBT that is ingested in the food may increase the dose attributed to tritium by not more than about a factor of two, and in most cases by a factor much less than this." The distinction between the comment on page 7 of the PHA and that from page 27 of the expert panel's report could be due to both inhalation and ingestion being accounted for by the PHA (although inhalation is barely mentioned in the report by the expert panel), while the panel's statement referred exclusively to ingestion. However, the sentence from the expert panel is a conclusion ("We conclude, therefore") and consequently attracts attention. The reader is thus left wondering why one source says a factor of 2 and the other says a factor of 1.2 to 1.3.

ATSDR Response: Most of the increased dose from consideration of the OBT dosimetry is due to ingestion of foods containing OBT. The reference on page 7 has been clarified by specifying that the dose increase factor of 1.2 to 1.3 is due to ingestion of tritium as OBT.

Page 9, 3rd complete paragraph, 4th sentence
Minor clarification suggested: insert the word "hypothetical" or "potential" in "past exposures", so that the sentence would read as "Relative to past potential exposures in…" or as "Relative to past hypothetical exposures in…"

Page 11, sidebar, last sentence
Since most of the potential contaminants of concern are determined by the ATSDR to not pose health hazards, suggest that the sentence be modified to read "Few contaminants from the site are at levels that would pose a potential health hazard."

Page 16, Table 2, "Comments and Status" associated with the East Taxi Strip Area
Suggest "1982-83" be added to the comment.

Page 16, Table 2, "Comments and Status" associated with the East Landing Mat Area
Suggest replacement of "Unknown" with "No longer used for storage. Ground water and soil remediation underway."

Suggest replacement of last sentence with: "Area is currently a parking lot and detailed characterization underway."

Suggest replacing "Unknown" with "Still in use pending transfer to LLNL's recently constructed Decontamination and Waste Treatment Facility."

Page 16, Table 2, "Comments and Status" associated with the Building 514 Area
Suggest adding the phrase: "pending transfer to LLNL's recently constructed Decontamination and Waste Treatment Facility."

Page 16, Table 2, "Comments and Status" associated with the Building 518 Area
Suggest adding the phrase: "Ground water and soil remediation underway."

Page 16, Table 2, "Comments and Status" associated with the Building 298/Fire Training Area. Suggest replacing "Unknown" with "Used as a storage area. Ground water and soil remediation underway."

Page 18, 4th complete paragraph, 1st complete sentence
For accuracy, suggest replacing "exceed" with "exceeded" as the maximum off site level of benzene is less than 500 ppb.

Page 20, 1st partial paragraph, 2nd complete sentence
Suggest replacing the word "accidents" with "inadvertently".

Page 45, second paragraph under Air
The current and historic doses mentioned (e.g., 0.26 □Sv/y) are ingestion doses only and thus probably don't belong in this section when ingestion is addressed in the following section (Biota). As well, the ingestion dose estimated by the expert panel was 0.11 □Sv/y (p. 62 July 2001 Final Report of the Expert Panel); the numbers cited by the PHA were mentioned in the expert panel's report but were calculated by LLNL for the 1999 LLNL SAER.

Page 46, first paragraph
The use of "maximum" for the "estimated cumulative annual doses" for 1965 and 1970 is misleading and should be removed. Table 3 (ATSDR, July 11, 2003) shows those doses as the means of their distributions. This paragraph should also make clear that the doses cited include doses from the annual routine releases.

Page 47, second paragraph
Again, remove "maximum" from "short term food ingestion dose".

Page 54, Table 12
In the footnotes, rather than say "Tritium doses are average total annual doses", why not say "…estimated annual doses for routine and accidental releases for the years of the large accidents'. If the reader just looks at Table 12 out of context, he may get the wrong impression. The tritium dose shown is the mean of the distribution for the acute releases plus the estimated dose from the routine releases for the years the acute releases occurred. This anomalously high dose (because of the contribution from the acute release) is being compared with the health guidelines for chronic, not acute, releases. It seems like it's an apple/orange situation.

Page 66, footnote
The effective half-life of HTO can be described as less than 15 days, but a 15-day half-life is on the low side if OBT is included. A longer effective half-life can be applied without negating the thesis of the paragraph, that the radiological dose from tritium is imparted within a year.

Page 90, third paragraph, last sentence
Rather than combining HTO and OBT half-lives, it would be better to mention that the effective half-life of HTO is from 5 to 15 days while that of OBT ranges from several tens to several hundred days (ATSDR Expert Panel).

Page 94, recommendation #1
Suggest starting the recommendation with: "ATSDR to".

23. The intended audience for this document is not clear. The technical level of the document may not be appropriate for the general pubic. However, there is occasional advice for the general public, such as in the section, Contaminants of Concern, p.53-64 which presents very useful summaries of available health effects information for the substances [boron, nitrate, etc.] found at elevated levels in ground and surface water at the site. The section on nitrate provided advice for families with infants. Perhaps the text might more appropriately read, "Families with infants should **be advised to** use…etc."

ATSDR Response: We agree that the technical level of this document is relatively high. Overall, the level of scientific understanding of the LLNL community is quite high and members of this community have requested that these documents not gloss over technical details. Also, these documents are only one of several communication tools used to convey information to the public. Upon release of the public health documents, ATSDR has held advertised meetings to present and discuss the findings using an informal question and answer format and also distributed non-technical fact sheets and flyers to the Livermore community.

24. Tables 9 and 12 of this document provide information on concentrations and cumulative

doses of specific contaminants found in ground and surface water associated with this site. Each measured value is then compared with “Comparison Values” and “Health Guidelines” in order to determine if there is a concern for health effects associated with that contaminant.

It is not clear how to relate these “Comparison Values” and “Health Guidelines” to specific documents in the reference list. Similarly, the values in the associated text [RMEGS, MCLGs, etc.] are not clearly referenced. Certain readers may want an opportunity to access and review these documents in order to gain an understanding of how these values were calculated.

ATSDR Response: The origins of the comparison values are presented in Appendix 4. The definitions of the specific terms are presented in Appendix 1 and the abbreviations for each of the comparison value terms have been added to the list of abbreviations.

25. The entire document would profit from a thorough editing/proofreading to catch grammatical errors [e.g., agreement of subject and verb, verb tense, punctuation, etc.] and stylistic inconsistencies. These can be distracting in an otherwise scholarly presentation.

Just a couple of examples include:
P47, paragraph 1: Ingestion of biota….. **present** a pathway [should be **presents**]

P48, paragraph 1: The following section **provided** [should be **provides**]
paragraph 2: HGs are **an estimate** [should be are **estimates**]

P55, paragraph 3: Estimated boron doses… **are** presented [should be **are**]

P70, Reference List-
Inconsistent use of periods in abbreviations [U.S. vs. US, D.C. vs. DC, after authors' initials].
Inconsistent use of italics with titles of journals

ATSDR Response: The above editorial comments have been addressed as appropriate and the entire document has been edited as suggested.